





VITAL CHEMISTRY.

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LECTURES

ON

ANIMAL HEAT.

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PUBLISHED BY REQUEST OF THE CLASS.

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GENEVA MEDICAL COLLEGE, October 22, 1844.

Prof. SPENCER :

Dear Sir :—At a meeting of the Medical Class, J. G. PELTON in the chair, it was unanimously resolved, that a committee be appointed respectfully to request a synopsis of your Theory which answers the question in Physiology, " Whence animal heat?"

Permit us to add, Sir, the pleasure it gives us individually, to present you the wishes of the Class.

JOHN J. BROWN,  
ISRAEL PARSONS,  
C. H. HAMMOND,  
ROBERT HUNTER,  
DAVID BURTON, }  
Committee.

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GENEVA, October, 1844.

GENTLEMEN : Your line of 22d, in behalf of the Medical Class, asking for publication a copy of my Lectures on animal heat, has been received. As soon as pressing avocations will allow the necessary labor of preparation, I shall cheerfully respond to the wish of the Class, to whom convey, and accept for yourselves individually, the assurance of an abiding interest in their welfare.

Cordially your friend,

THOMAS SPENCER.

Messrs. BROWN, &c., Committee.



## P R E F A C E .

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The following Lectures are the results rather of occasional moments of leisure from the duties of an active professional life, than of a special devotion to the cultivation of the more inviting field of Chemistry and Physiology. For the facts upon which the discussion mainly depends, I am indebted to those who have more particularly devoted their attention to these subjects, while the deductions are the results of my own reflections.

An attempt to explain the vapor of the pulmonary excretion, led me by successive steps to a belief, not only in the intimate chemical relations of respiration and calorification, but of all the functions and phenomena of organic life. If every step has been fortified by ascertained facts and the deductions have been legitimately drawn, a **CIRCLE OF VITAL AFFINITIES**, uniting all the structures and functions of the organism, and making each set of capillaries mutually dependent on and balanced by others, in the chemico-vital changes produced upon their passing currents of blood, has been deter-

mined. That such a series exists, and that the links in the chain may be demonstrated, can not be doubted; but in view of the intricacy of the subject, and of my limited knowledge of experimental chemistry, a due distrust is still felt in the accuracy of the attempted determination.

Much allowance is demanded upon the ground of the hasty manner in which (to answer the wishes of the class) it has been necessary to send these sheets to the press. Indeed the term must have closed without this being effected but for the assistance of a young friend, especially in the preparation of the Diagrams. I could have desired a more careful revision before submitting the results of my inquiries to public criticism. If, however, they shall contribute in any degree to elucidate the hitherto obscure subject of Vital Chemistry, the end of their publication will be attained.

Geneva, N. Y., January, 1845.

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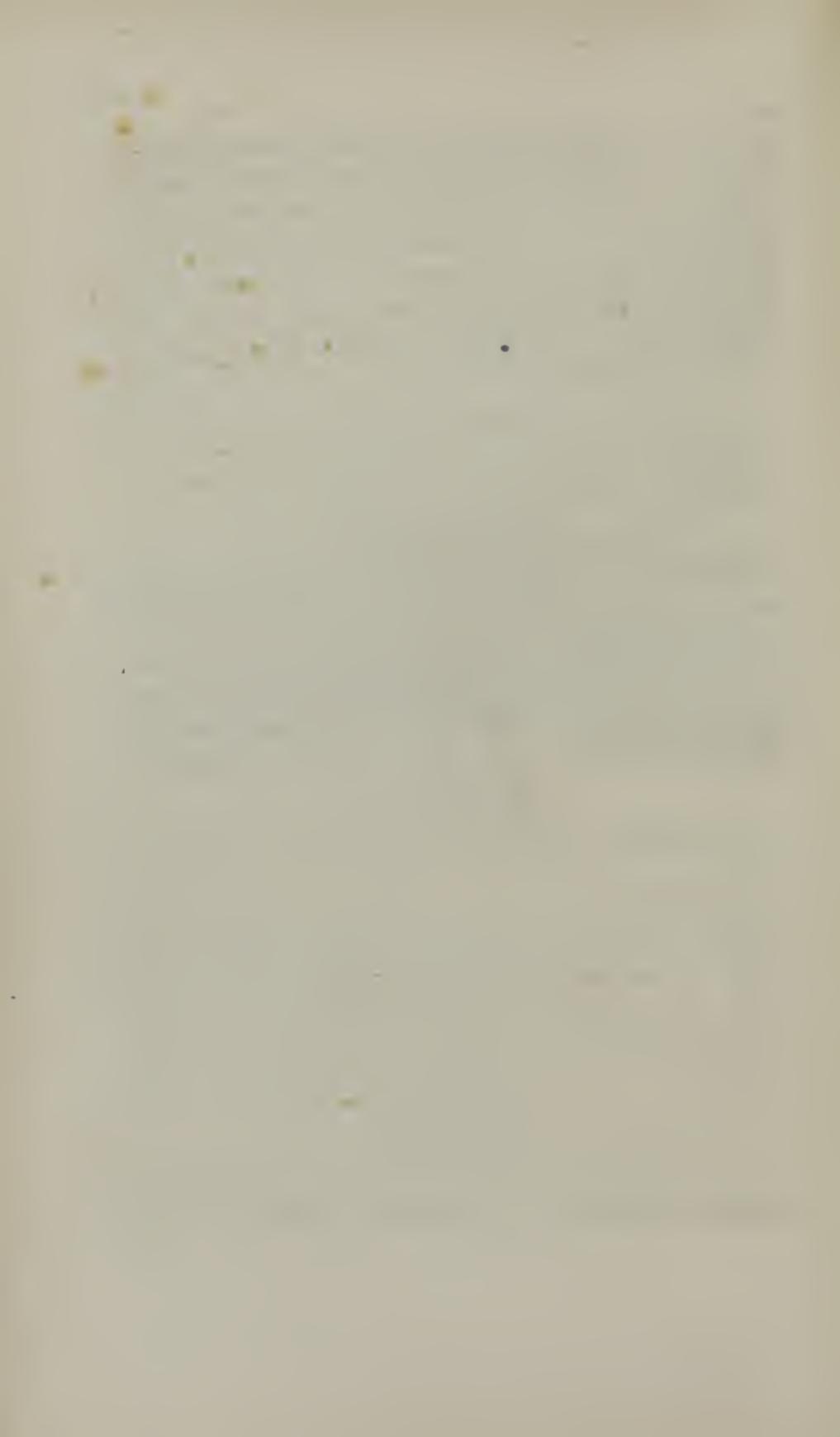
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# LECTURE I.

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## CHAPTER I.

OF THE MECHANISM AND VITAL MOVEMENTS OF  
THE APPARATUS OF RESPIRATION. [*Omitted.*]

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## CHAPTER II.

OF THE CHEMICO-VITAL CHANGES PRODUCED  
BY RESPIRATION UPON THE BLOOD AND RESPired  
AIR.

### § 1. *General remarks and facts.*

Atmospheric air is to the lungs, what food is to the stomach, except that it principally aids in withdrawing materials from, instead of becoming a nutrient addition to, the mass of circulating fluids. In the relation of the lungs and air tubes to the medium in which we live

and breathe, we observe an admirable adaptation. The air, by its elasticity and pressure, penetrates every cavity which communicates externally, and thus prevents a vacuum ; while a denser fluid could not penetrate into, and be in rapid succession expelled from, the complicated tubes and minute air cells of the lungs during inspiration and expiration. The specific gravity of atmospheric air is 770 times less than that of water, and a column of it, about 40 miles high surrounding the earth, is equal to a column of water of the same diameter 32 feet, or of mercury thirty inches in height. The living man of ordinary size has, therefore, to sustain the enormous pressure of thirty or forty thousand pounds weight of atmosphere while life continues.

§ 2. I need hardly mention that atmospheric air is a compound of Oxygen, Nitrogen, and Carbonic acid, in about the proportion of 21, 78 and 1. It also contains the imponderable elements, light, heat and electricity ; watery vapor, and exhalations, holding in solution vegetable and animal matters, with other accidental admixtures. To the Oxygen, however, are we principally indebted for sustaining life. This gas not only sustains life, but is the great sup-

porter of combustion, and of chemical change in the operations of inanimate nature, and forms an important ingredient in a variety of compounds, such as oxides, acids, water, and various animal and vegetable substances. Nitrogen, on the contrary, appears to be a kind of negative element of atmospheric air. It is, however, one of the elements of animal bodies, and experiments appear to prove that it is both absorbed by, and expelled from the lungs during respiration.

§ 3. The other ingredient of atmospheric air, *Carbonic acid*, is one of the all-pervading substances of nature, is contained in the water we drink, forms an important ingredient in the food of plants, and, as I proceed, I shall assign to it, in the production of some vital phenomena, a higher agency than has hitherto been done.

*This agency I believe to be the evolution of animal heat at every point of the body by the decomposition and recombination of this gas.*

§ 4. *Old views of calorification.*

For a long period, the lungs were regarded as the seat of the evolution of animal heat, and it was believed that from this point it was distributed to every part of the body. After the discovery of Oxygen, its absorption by the lungs,

giving off the latent caloric, which thus became sensible in the various tissues of the body was supposed to be the immediate cause of animal temperature. But more rigid experiment and inquiry appear to prove, that instead of Oxygen entering the capillaries and combining with blood in its transmission through the lungs, it is principally employed in converting the carbon of the blood into carbonic acid. Doctor OLIVER says, "upon analyzing a portion of air which issues from the lungs in expiration, it is found that the proportion of its elements has undergone a considerable change, and this change is found to consist in an increase of the carbonic acid, a diminution of the Oxygen, and an addition of a large quantity of watery vapor containing some animal matter in solution."

### *§ 5. Established facts of physiology.*

It is now proposed to explain the changes produced by the vital Chemistry of the Pulmonic and systemic Capillaries upon the blood, as connected with the functions of Respiration and Calorification, from the following and other well established physiological facts :

1. A considerable quantity of insensible watery vapor is constantly evolved from the Lungs.

2. Notwithstanding this rapid vaporization from the blood in the Lungs, the blood returns from the Pulmonic, much thinner than from the systemic Capillaries.

3. Atmospheric air which has been respired is found to have lost about 7 per cent of its Oxygen.

4. The same air contains an increase of Carbonic acid of about 7 per cent, containing, nearly, the 7 per cent of Oxygen.

5. The blood is freed of its darkening pigment, or, as usually expressed, the blood is decarbonized by transmission through the Capillaries of the Lungs.

6. By this depuration, the blood is changed to a vermillion color.

7. This coloring or carbonaceous pigment is incessantly formed in the entire mass of blood during its transmission through the systemic capillaries.

8. In vegetable physiology, the vital action of the Capillaries of the leaves, decomposes the Carbonic acid of the sap, and forms woody fibre, a triple compound of Carbon, Oxygen Hydrogen, generally in the proportions of water and called lignin or humus.

9. In the growth of trees, this compound, af-

ter its formation, and while still suspended in water or sap, is carried back to the body of the tree, is deposited upon its exterior, beneath the bark, to contribute to its growth, constitutes almost the entire solid portion of this vegetable, and forms the annual layers or grains of wood.

10. Vegetables evolve from their leaves the Oxygen of the Carbonic acid, which their Capillaries decompose.

§ 5. *Composition of the venous pigment unknown.*

1. Although generally admitted by modern physiologists that decarbonization is the principal vital office of the lungs, the nature of the carbonaceous substance pre-existing in venous blood, seems by no means to have been satisfactorily determined. In attempting to settle this point, by proving that the same triple compound of Carbon and the elements of water is formed by animal, as by vital vegetable chemistry; and that its formation in the systemic capillaries, and its expulsion from the pulmonic, constitute the immediate cause of the vital function of Calorification, I shall endeavor to conduct you through the same pathway by which I reached these conclusions. So doing, if I wander from the rule which should

guide all our medical inquiries,—that of having every step of our progress sustained by indubitable facts,—the corrective may be applied by those who go with me in pursuit of physiological truth, if they rigidly scrutinize for themselves the facts and reasonings.

§ 6. § III. *Laws of free and latent Caloric.*

Preliminary to investigating the first fact stated, that vapor is thrown off from the lungs, it seems necessary to present a few remarks on the laws of caloric. This is considered necessary, in view of the facts, that many of my class are just commencing their medical studies, and that my able colleague in the chemical chair, has not reached this subject of his course.

§ 7. Water is capable of assuming three forms—the solid, fluid and æriform, or that of vapor. These changes are produced by heat, or caloric. By caloric is meant the agent which produces in us the sensation of heat. The term heat is used in a two-fold sense; in the one implying the sensation produced upon touching a hot body; in the other, it is synonymous with caloric—that is, the agent, or cause of the sensation. Heat or caloric is supposed by most chemists to be a very subtil flu-

id, and as such I shall now consider it. As I shall have occasion to use the term,—*free* heat, or caloric,—I would define it to be the heat which is readily transmitted from body to body, and which, hence, readily affects the thermometer. By *latent* heat is meant the kind which appears to combine chemically with the atoms of bodies, and when so combined, it does not affect the thermometer.

#### § 8. *Latent heat combines with gases.*

In union with Oxygen, it holds it in the gaseous state, and remains chemically combined with it, until the Oxygen enters into new combinations, when it is set free, and, as soon as it is thus set free, it affects the thermometer. Again, Hydrogen gas is Hydrogen combined with latent heat which keeps it in the gaseous state till it enters into some new combination, when this heat is set free.

#### § 9. Different gases as well as different fluids do not possess equal *capacities* for latent heat ; that is, one will combine chemically with a larger amount than another of like bulk. This is proved by experiments which disengage this latent heat, and set it free from bodies ; that is, when thus set free, this free heat contained in a given bulk of one body, will raise the thermom-

eter two, three, or four times as much as the latent heat of another body of the same bulk. The body whose latent heat, on being set free, raises the thermometer most, is said to have the greatest capacity for latent heat.

§ 11. *Latent heat combines variously with water.*

Water in its fluid state is combined with latent heat. Vapor is water combined with an additional proportion of latent heat, and when it condenses, the latent heat is again set free. Hence, in frosty weather, the vapor from the lungs loses its latent heat, and the water may be seen, as condensed on breathing upon window-glass or other cold substances. Fluid water is held in that state by latent heat; but when it freezes, this latent heat is set free and becomes sensible. When, on the contrary, ice melts, the water again combines with free heat, which then becomes the latent heat of fluidity in the water. Heat, probably, unites in definite proportions, like the other elements of nature. When water is converted into vapor, it combines with the free heat of surrounding objects, and this heat then becomes latent in the vapor. But

## § 11. § IV. OF THE PULMONARY VAPOR.

To convert water into vapor, requires a large amount of heat. Is the source of animal heat the body, or is it external? When the water of the blood is converted into vapor, as it is in the lungs, there must either be a rapid absorption of free heat from the body, or heat must be obtained from an external source to supply the latent heat of the vapor.

§ 12. 2d Fact: *Examined.*

Let us next examine the *second fact*, that the blood becomes *thinner* by its transmission through the lungs. This thinning occurs, notwithstanding the large amount of watery vapor and carbonic acid gas evolved. It seems fair to infer, from this fact, that the excretal substance thrown off is composed of dense atoms, mechanically suspended in the albuminous serum of venous blood, and that its expulsion by the chemico-vital action of the air vesicles thus thins the sanguineous mass. The pulmonary vapor and gas thrown off would otherwise *thicken* the blood.

§ 13. *The pulmonic and systemic capillaries antagonise each other.*

As no essential chemical change takes place

in the blood in the large vessels, the vital process which forms these dense atoms must, obviously, be seated at the points where the blood passes from the systemic capillary arteries to their corresponding veins. The pulmonic and systemic red capillaries must hence antagonize each other ; the systemic incessantly separating, the pulmonic throwing off the carbonaceous matter into the atmosphere. After passing the systemic capillaries, as the blood, in every, the minutest portion, exhibits a like uniform change of color, all portions must receive a like ratio of coloring deposite. As no chemical change occurs in the large vessels, the element or elements which compose the coloring pigment of venous blood must, obviously, have pre-existed in every atom of arterial blood, before passing the systemic capillaries. That this elemental carbon of arterial and venous blood must be in different forms of chemical combination, after having been subjected to the action of the respective vital laboratories of the antagonizing sets of pulmonic and systemic capillaries, cannot be reasonably doubted.

§ 14. *But of the 3d and 4th Facts. (§ 5, above.)*

Before attempting to decide in what form,

simple or compound, this eliminated carbon or pigment exists in each set of capillaries, let us examine the 3d and 4th facts stated, viz: that respiration air loses about 7 per cent. of Oxygen and gains 7 per cent. of Carbonic acid gas. All substances, as well as water, in changing from a fluid to a solid form, set their latent heat free, and in changing from a solid to a fluid, or from a fluid to an æriform state, abstract heat from surrounding objects.

§ 15. It must hence be obvious, that to convert the solid carbonaceous pigment of the blood into the Carbonic acid gas, this must draw heat from the body as would the watery vapor, or there must be an external supply of caloric. There are then two substances thrown from or formed in the lungs—vapor and carbonic acid gas—both of which require a large amount of free heat to form and preserve them in the æriform state in which they are expelled. There must therefore be a very rapid production of heat by the body to carry off this Carbonic acid and watery vapor, in respiration; or an unceasing supply of Caloric must be drawn from some source exterior to the body. To throw off such a large amount of gaseous substances, this supply of heat must,

necessarily be so rapid that it appears hence reasonable to infer that it must be derived from some external source.

### § 16. What is this *external* source of Caloric?

The atmospheric air respiration loses, as I have before stated, about 7 per cent. of its Oxygen, and the blood its carbonaceous pigment by respiration. Carbon and Oxygen are the two elements of carbonic acid gas, they are brought into contact in the lungs, and if an amount of Oxygen in the carbonic acid thrown off, is equal to that of the Oxygen lost from the air in respiration, as stated in the 4th fact, it appears reasonable to infer that Carbon and Oxygen combine *chemically* to form the carbonic acid gas eliminated. The latent heat of the Oxygen in its chemical combination with the carbon of carbonic acid, would keep it in the aerial form. No heat would therefore require to be drawn from the body itself, for converting the carbon into the gaseous form, provided the Oxygen entering into the composition of the carbonic acid gas contained a sufficient supply of latent caloric; or in other words, if Oxygen has as great a capacity for latent heat as carbonic acid gas.

*§ 17. Carbonic acid, and Oxygen gases, have different capacities for latent heat.*

Is the latent heat of the Oxygen taken from the atmosphere precisely sufficient, or is it more, or is it less, than is requisite for forming the carbonic acid gas evolved?

Carbonic acid gas, you are aware, can be readily formed by the combustion of carbon in Oxygen gas. In this process, carbon combines chemically with Oxygen, and carbonic acid gas is the result. It accords with the well established chemical laws before referred to, that if the Oxygen contained less than the carbonic acid which was formed, the combination would cool the surrounding medium by absorbing its free heat; whereas, if the Oxygen gas employed contained more latent heat than the resulting carbonic acid, the caloric being set free, would raise the temperature.

You are aware that a large amount of sensible heat is evolved, or set free, during the combustion of carbon, or charcoal, and its conversion into a gas; and hence, the irresistible conclusion, that the Oxygen gas employed in this chemical change contains more latent heat than the carbonic acid gas formed. From this

it must follow that there is an excess of latent heat set free in the air cells of the lungs by the conversion of the carbon of the blood into gas, in its combination with Oxygen. That is, Oxygen gas has a greater capacity for, and contains more, latent heat than carbonic acid gas.

§ 18. The combination of Oxygen and Carbon in the lungs must produce an elevation of temperature in them, precisely as when we burn charcoal, and *this would cause a great evolution of sensible heat in the air cells.* This conclusion drawn from the facts stated is fully confirmed by Crawford, Dalton and other old chemists, who estimate the amount of latent heat contained in Oxygen at nearly four times that contained in Carbonic acid gas. The relative capacities for latent heat are not as disproportionate according to more modern chemists, but all agree that Oxygen has the greatest capacity for latent heat. Be the relative capacity what it may, *the oxydation of carbon always evolves heat, and sensibly raises the thermometer.* The Carbon thrown off from the lungs, is, obviously, subdivided into its ultimate atoms, and hence *spontaneously* ignites on meeting atmospheric air, and a large amount of free heat must consequently be set at liberty in the air cells

of the lungs, producing there a sort of combustion. What! combustion in the lungs! This chemical change, but for a wise provision for disposing of this excess of caloric, would produce inevitable death.

§ 19. What is this provision? What is this safety-valve of the lungs? I have before stated that the pulmonary vapor must, necessarily, absorb a large amount of free heat from the body, or that there must be some external supply of caloric. The oxydation of the carbon would abundantly supply the watery vapor with its needful latent heat, so that the vaporization of these two gaseous substances would not, as otherwise, cool the body, but would derive their caloric from the atmospheric Oxygen employed, and at the same time extra caloric would be set free to heat up the organism. That the necessary caloric for converting the water and carbon into the gaseous forms is taken from the mass of blood in its transmission through the lungs, is entirely irreconcilable with the fact that the blood in the left cavities of the heart is warmer than that in the right. Again, the rapid absorption of heat by the rapid vaporization of water and conversion of carbon into carbonic acid gas must, inevitably, cool

the vital fluids, but for the supply of heat derived from the Oxygen of the atmosphere.

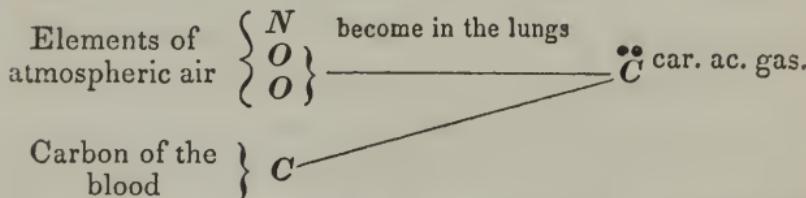
§ 20. Is the *carbon* of the carbonic acid, before oxydation in the lungs, in its simple, *elemental* state, or is it *combined* with other elements? Simple, uncombined elements are not, generally, if ever, expelled from animals. Binary compounds are those common to inorganic chemistry; while more complex compounds are peculiar to vital chemistry. If the carbonaceous pigment of venous blood be a triple compound, as probable, *with what elements is the carbon combined?* Oxygen and Hydrogen are the elements of the watery vapor thrown off from the lungs, and if united with the carbon, would form a triple compound of water and carbon, like the lignin or humus of woody fibre as named by chemists and vegetable physiologists. These facts render it probable that the carbonaceous pigment expelled, is the same triple compound as in vegetables, and if so, may hence be properly designated, *Hydrate of Carbon*. Although there are several theories of respiration, it seems satisfactorily established that the alteration of color in the blood in the *pulmonic* capillaries is essentially dependent upon the chemico-vital

changes, I have detailed. An explanation, however, of the chemical change altering the blood in the systemic capillaries from a *vermilion* to this *dark* color of venous blood, has perhaps never been satisfactorily made by any physiologist. This I shall now attempt, and in connection with it, shall offer an explanation of the *evolution of animal heat, called the function of calorification*. The fact that venous blood is reddened by exposure to atmospheric Oxygen, and carbonic acid given off precisely as when exposed in the lungs appears to settle the point, that carbonic acid gas is a *product of, not an educt from*, the blood of the pulmonic capillaries.

§ 21. Let us now sum up the prominent points determined.

1. Carbonic acid gas is formed in the lungs by the oxydation of Carbon from the darkening *pigment* of venous blood.

DIAGRAM 1.



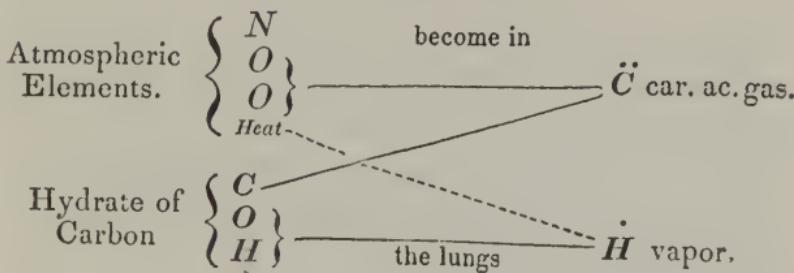
2. The oxydation of the carbon imparts to

water *free* heat, which uniting with it, as *latent* heat, forms vapor.

3. The carbon of the *coloring pigment* which is cast off from the lungs, must be *elemental* atoms of carbon, or a *compound* of this element.

4. The pigment is *probably* a compound of the elements of water and carbon; and if so, the changes in the lungs may be thus illustrated:

DIAGRAM 2.



# LECTURE II.

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## CHAPTER III.

OF THE CHANGE OF COLOR AND CHEMICAL PROPERTIES, PRODUCED UPON THE BLOOD BY THE SYSTEMIC CAPILLARIES.

Facts to be examined, [§ 5, 5 to 10.]

Questions to be answered: 1, Is the carbonaceous pigment formed by the systemic capillaries in form of elementary atoms ? Or 2, Is it a compound of carbon and water ?

§ 22. § V. OF THE CHANGE OF COLOR IN BLOOD.

The 5th and 7th Facts that the blood is reddened in the lungs by parting with a carbonaceous pigment; and is darkened in the systemic capillaries by its formation there, seem conclusively to show that the elemental Carbon there-of *undergoes changes in its chemical relations or combinations*, with the other simple elements

of the blood at both these points of the organism. The fact, also, that Carbonic acid gas applied to arterial blood out of the body darkens it, precisely as when the blood passes the systemic capillaries, appears fully to establish the same point.

This fact seems also to justify the belief that Carbonic acid is *decomposed*, in passing such capillaries to form the carbonaceous pigment sent from this point to the lungs and skin for elimination. The farther facts, that out of the body, arterial blood is darkened by applying to it Carbonic acid, and that it is again reddened by applying to it Oxygen, precisely as when the venous pigment unchanged reaches atmospheric air in the lungs, seem to prove that the Carbonic acid is—*First, decomposed* by the action of some of the elements of blood upon it, and—*Second, recomposed* by the after application of Oxygen to the darkening pigment.

Now it is obvious that as the carbonaceous pigment, in being sent from the systemic to the pulmonic capillaries undergoes no chemical change or change of color, the conclusions seem irresistible that the same chemical changes occur in arterial and venous blood, by the application to them respectively of Car-

bonic acid and Oxygen out of the body as in it; and that hence the systemic and pulmonic capillaries must antagonise each other, by the one set decomposing, the other recomposing Carbonic acid.

But these facts and deductions do not settle the undetermined point left in our last Lecture, *whether the pigment is elemental Carbon, or a compound of it.* That directly opposite chemical changes take place in the pulmonic and systemic capillaries; that *Carbonic acid* is RECOMPOSED in the pulmonic capillaries, as already explained, while the same gas is DECOMPOSED in the systemic, and that these two systems of vessels are thus the counterparts or antagonists of each other, seem alike inferable from the following facts: *while they also show that water is chemically combined as a triple compound of carbon, by the vital action of the systemic capillaries, to form the pigment of venous blood;*

§24. 1. Directly opposite changes of color take place in the pulmonic and systemic capillaries, the one changing the blood from dark to red; the other from red to dark. If the expulsion of a carbonaceous substance, whatever its chemical composition, changes the blood from a

dark to a vermillion color in the lungs, it is most obvious that the formation of this very substance in the systemic capillaries changes the blood from vermillion to dark.

It appears to be a generally admitted physiological fact that the serous capillaries are the ingenious architects which select the materials and build up the various parts of the organism, while, on the contrary, the red capillaries have been considered only in the light of common carriers. But it is believed that they are not restricted to this humble office ; but are connected with the function of calorification.

§ 25. 2. The change of color produced by the transmission of the blood from every minute capillary artery to its corresponding systemic vein, to a dark color, is just as uniform as is the change to a vermillion color between the minute, pulmonic vessels ; and there must, obviously, be as unceasing a supply of the elementary Carbon in the systemic capillaries, as there is expulsion of it from the pulmonic and cutaneous capillaries. In health the elimination of carbon from the lungs and skin thus constantly balances the amount supplied in the systemic red capillaries, and thus darkens every atom of the venous blood. But

3. What is the source of the elemental carbon of the venous pigment? It is obvious that to supply the atoms of carbon, for the incessant formation of the carbonaceous pigment, a large amount of this element must pre-exist in the blood as free carbonic acid gas, or that it exists in some of its compounds; it being estimated by Lavoisier, and several subsequent experimenters, that at least twelve ounces of pure carbon, or charcoal, are required to be thrown off by the lungs every twenty-four hours, to form the whole volume of Carbonic acid gas expelled. Davy, Allen, and Pepys think that more than twelve ounces are expelled; Muller thinks this an over estimate; while Liebig estimates it at 13. 9 ounces.

This elementary Carbon combined with Oxygen, forming the Carbonic acid gas, of whose many important offices in nature I have before spoken, is readily, when set free in the stomach, assimilated by the digestive organs, and like water it is rapidly conveyed into the mass of circulating fluids.

In addition to free Carbonic acid in arterial blood, it is also combined with various compounds found in this fluid, such as carbonated alkalies.

“Mr. Brande (says Dr. Good) has established by experiments, that Carbonic acid does exist, and that, too, in a considerable quantity, in the blood of animals, while circulating through both arteries and veins; and that it is so largely poured forth by blood placed while warm under the receiver of an air pump, as to give the appearance of effervescence, a fact familiar to Boyle two hundred years ago.”

The venous and arterial blood, according to Mr. Brande’s experiments, seem to contain a equal proportion of this gas, and he calculated that not less than two cubic inches were extricated from every ounce of blood thus experiented upon. The works of Muller, Carpenter and other able writers of modern date, abound in the proof that both arterial and venous blood contain Carbonic acid. From all the sources referred to, it seems probable that there would always be in the mass of circulating fluids, a sufficient supply of Carbonic acid from which could be abstracted the uninterrupted supply of Carbon for the carbonaceous pigment first formed in the systemic capillaries.

§ 27. 4. *No carbonaceous substance so universally pervades nature, as Carbonic acid.*

5. Vegetable physiology furnishes an analog-

gy which sustains the belief that Carbonic acid is decomposed in the systemic capillaries of animals, to furnish the Carbon of the carbonaceous pigment of venous blood. Carbonic acid is regarded as an essential food of plants; its decomposition furnishes the Oxygen evolved from their leaves, while the elementary Carbon is deposited to form a part of the body of the plant. The systemic capillaries are the vessels which perform the *vegetative or vital* growth of animals; and analogy would lead to the belief that the capillaries of vegetables and animals may alike decompose Carbonic acid.

As already noticed, [Fact 8, § 4 plus 1,] it is a generally admitted fact that Carbon in vegetables combines with water, in form of woody fibre; in other words, wood is a triple compound of Carbon, Hydrogen and Oxygen, called *humus* or *lignin*; and this, upon analysis in some kinds of wood, is found to be a compound of Carbon in union with Oxygen and Hydrogen in the definite proportions of water.

§ 29. *Oxygen evolved from leaves, absorbs heat from water.*

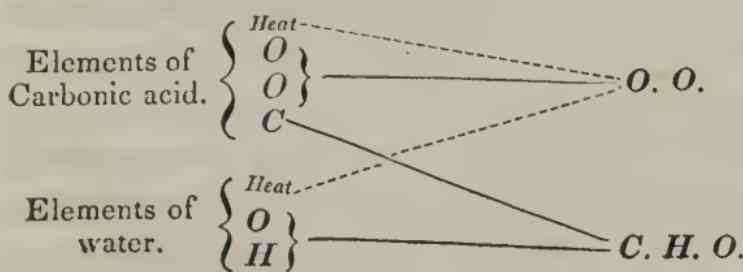
I have already stated the estimate of Dalton and other old Chemists, that Oxygen contains four times as much latent heat as Carbonic acid

gas. I have myself furnished the proof that it contains a much larger amount; and modern Chemists agree in the general fact, that Oxygen has a greater capacity for latent heat than Carbonic acid, although the difference is not as great as estimated by Dalton.

In the formation of Hydrate of Carbon, therefore, by the capillaries of the leaves in vegetables, there must be some other source of Caloric than the latent heat of the Carbonic acid, to convert its Oxygen into the gaseous state in which it is evolved. This requisite amount of heat must hence be supplied from the water which, in combining with the Carbon, gives off its latent heat of fluidity to the Oxygen thrown off from the Carbonic acid. If so, it follows that the atoms of Hydrate of Carbon, as deposited for the growth of vegetables, are minute solids.

§ 30. Thus illustrated :

DIAGRAM 3.



The water and Carbon, on assuming the solid form in the Hydrate of Carbon, furnish to the Oxygen the heat necessary to its existence in the gaseous state.

§ 31. *Other proof that C. H. O. is a solid.*

That Hydrate of Carbon is a solid, may also be fairly inferred from these facts : 1. That this compound of Carbon forms the basis of the solid wood we burn ; and 2. That the driest wood, upon combustion, yields Carbonic acid gas and watery vapor by the oxydation of the Carbon. If Hydrate of Carbon in these aggregated masses, be a solid, its minutest elementary subdivisions are also, obviously, solids.

§ 32. Not only does Carbonic acid play an important part in the formation of the vegetables which cover the surface of our globe, but it enters into the composition of numerous minerals in the bosom of the earth, and also furnishes, by slow process, through the medium of vegetable growth, the elementary Carbon of our extensive coal mines. The modern theory of the formation of these is, that the layers of coal were of vegetable origin, and that the water of the Hydrate of Carbon of the vegetable fibre being gradually separated by heat and vaporization from the Carbon, this is left in the

form of coal ; that is, the earth here becomes a large coal pit.

All of you, young gentlemen, must be familiar with a coal pit. In this, wood is subjected to heat without atmospheric air being admitted, in order to vaporize the water of the wood, leaving the Carbon in porous masses of coal. So the bosom of the earth, by its internal heat, slowly drives off the water from the vegetable layers, converting them into mineral coal.

§ 33. *Other analogies of animals and vegetables.*

6. There are numerous other striking analogies between animal and vegetable life ; both possess a living principle by means of which they convert the elements of extraneous substances to their own uses and growth ; Carbonic acid constitutes an important ingredient in the food of both, and vegetables, by a vital process of their minute vessels, decompose this gas, appropriating its elementary Carbon to their use and growth.

The experiments of Muller, and the facts of Liebig and other physiologists, appear to prove conclusively, that free, as well as combined Carbonic acid, exists in the arterial blood of animals from which this compound could be

formed, as in vegetables ; and it appears fair to infer that, as the minute vessels of animals possess like vital properties as those of vegetables, they may also decompose this gas, and form the Hydrate of Carbon. Admit this inference from analogy to be true, and it must be obvious that the atoms of Hydrate of Carbon in the blood must be as much minute solids, as when deposited in vegetables, or as congregated in masses in the wood we burn ; facts before proved.

§ 34. *Comparative uses of C. H. O. in vegetables and animals.*

This Hydrate of Carbon, as soon as formed in vegetables, is deposited to contribute to their growth ; there being no return circulation. On the contrary, this compound does not contribute to the growth of animals, but as soon as it is formed in them, it becomes an excretal substance, requiring to be immediately eliminated from the body by the lungs and skin, in the manner already explained.

The facts, that the blood loses its *dark* color, and becomes *thinner* in passing the lungs, are readily explained upon this theory, the dense atoms of the darkening pigment obviously thickening and coloring venous blood. The vapor-

zation of the water, and the Carbonic acid gas evolved, would, inevitably, thicken the blood, unless their elements pre-existed in a more solid form in the venous blood brought to the lungs, than in arterial blood.

You may say, from what has been advanced, that these dense atoms of Hydrate of Carbon, being the components of woody fibre, must be infinitesimal blocks of wood, floating in the sanguineous mass. This is, doubtless, true; and let us now see if we can trace any analogy between the burning of aggregated atoms in form of blocks of wood, and the combustion of these atoms of Carbon in the lungs.

§ 35. *Of the analogy of pulmonic combustion of Carbon and the burning of wood.*

When the driest baked wood is set on fire, and the attraction of cohesion is thus overcome, it burns rapidly; Carbonic acid gas, and a large amount of watery vapor are generated. Here the Oxygen of the atmosphere combines with the Carbon, forming Carbonic acid gas, and the excess of latent heat of the Oxygen gas, over and above what is necessary to convert the Carbon into the gas, combines with the water of the Hydrate of Carbon and converts it into watery vapor. In this process the

heat overcomes the attraction of aggregation of the wood, when the Carbon becomes at once oxydized and the water vaporized.

§ 36. *Analogy of pulmonic oxydation and that of decay in wood.*

But, have we any analogy in the natural decomposition of solid lignin, or Hydrate of Carbon? Decaying wood, called, in popular nomenclature, *spunk*, may be cited. This is *luminous* in the dark, owing to the gradual oxydation of the Carbon; and the evolution of Carbonic acid gas and watery vapor slowly going on, as the attraction of cohesion is overcome by decay.

In the lungs, the Hydrate of Carbon, in its condition of molecular solids, alike burns spontaneously. Why vegetables growing in mines are luminous, is explicable from their having no bark, and from the small amount of Hydrate of Carbon formed by them, hence coming in direct contact with atmospheric Oxygen.

A thought here may be worth remembering: Hydrate of Carbon or wood, seems to be about intermediate in density between the extreme density of its pure element of Carbon, as formed in diamond, and water as a fluid; a medium to be expected in such compounds of the two

elements. In the formation of the two gaseous compounds in the lungs and on the surface, the latent heat of the Oxygen of the atmosphere must, in like manner, as in burning wood, convert the water of the Hydrate of Carbon into the *insensible respiratory and perspiratory vapor.*

From the facts and analogies examined, finding as we do, not only identity of phenomena, but of cause, we may fairly infer that the vital chemistry of vegetables and animals in the formation of Hydrate of Carbon, is identical. It seems alike true that the laws in both harmonise with the chemical laws of inorganic chemistry. If so, exposing arterial blood out of the body to Carbonic acid should, obviously, darken its color, and form Hydrate of Carbon as in the systemic capillaries; while Oxygen applied to venous blood should, as in the lungs, redden it, and produce Carbonic acid; both well observed facts, as stated by Liebig, and as before noticed. If to these facts, as direct deductions from our analogies, we add the further facts, *first*, that arterial blood, darkened by Carbonic acid out of the body, is again reddened by Oxygen; and *second*, that Carbonic acid and vapor are given off upon exposure to

Oxygen, precisely as in respiration, the proof seems again indubitable that the pulmonic and systemic capillaries perform the *antagonist functions of composition and decomposition* of Carbonic acid.

The Hydrate of Carbon on coming into contact with Oxygen, ignites, and forms Carbonic acid gas, and the excess of Caloric in the Oxygen converts the water of the hydrate of carbon into vapor, or halitus, and the blood hence becomes reddened out of the body precisely as in passing through the lungs. From all these facts and analogies, I cannot resist the conclusion, that carbonic acid gas is decomposed in the systemic red capillaries, that there is formed precisely the same triple compound in animals, as in vegetables ; the hydrate of carbon.

§ 38. This theory of respiration differs essentially from that of Lavoisier, La Place and Prout, which supposes Carbon and Hydrogen, or hydro-carbon, to exist in the blood, and that Hydrogen and Carbon both become oxydised by respiration. Hydro-carbon is a mere imaginary compound, which was necessary to complete their theory, while hydrate of Carbon as just shown is an extensive triple compound.

§ 39. From the facts already considered, and

the fact that respiration can be but for a moment suspended without inducing death, is not the conclusion irresistible that the importance of the lungs to life is dependent upon the pulmonic capillaries preserving the balance, by throwing off hydrate of carbon as fast as it is formed by the systemic capillaries? If so, can we doubt, that such formation is, itself, connected with some important office of vitality? In vegetable physiology, hydrate of Carbon fulfils the important office of contributing to the growth of plants, and as it serves this useful purpose, and since it does not help build up the organism of animals, it can hardly be doubted, that it contributes in animal life to some important function not found in vegetables.

With what function is it connected? This leads me in the next place to speak,

## CHAPTER IV.

### OF THE FUNCTION OF CALORIFICATION.

§ 40. In burning wood, the Carbon and water are not only converted into gaseous forms, but a large amount of free heat is thrown off. The same thing must, obviously, occur in the lungs to some extent from the like chemical changes, and this chemical combination would, hence, tend to elevate the temperature of the blood. This may, obviously, be one source of animal heat, and accounts for the blood in the left cavities of the heart being one degree or more higher than in those of the right.

§ 41. Moreover, although the chemico-vital process going on in the lungs would be an incessant source of animal heat, yet the universal and equal diffusion of temperature throughout all parts of the body appears to disprove its being the *only* source, and, indeed, conclusively to show, that animal heat must, in some way, be measurably, if not principally, generated in the systemic, instead of the pulmonic capillaries. The experiments of Dulong show that more heat is generated by animals than could be done by this conversion of Carbon into Car-

bonic acid gas by the lungs, and that hence some additional mode of generating heat must exist in the functions of the systemic capillaries. (*Hare's Chem.*, 507.)

§ 42. From the earliest records of science, respiration and calorification have been believed to be intimately connected; and ancient theories made the lungs the centre, from which heat radiated to every part of the organism; but the simple fact of the equal distribution of heat to every point, overturns, I think, this doctrine.

A second doctrine taught, that the Oxygen absorbed by the blood in the lungs, gave off its latent heat in all parts of the body, and thus preserved the elevated temperature of animals.

§ 43. As already explained, rigid experiment and induction appear to prove that the Oxygen employed in respiration, is principally used in decarbonizing the blood. We have heretofore proved, that water, in uniting with Carbon in vegetables, gives off its latent heat of fluidity in forming a solid atom of the Hydrate of Carbon. Facts also justify the conclusion, that the formation of solid atoms of Hydrate of Carbon in the systemic capillaries of animals, results from the like decomposition of Carbonic acid.

*§ 44. Immediate cause of animal heat.*

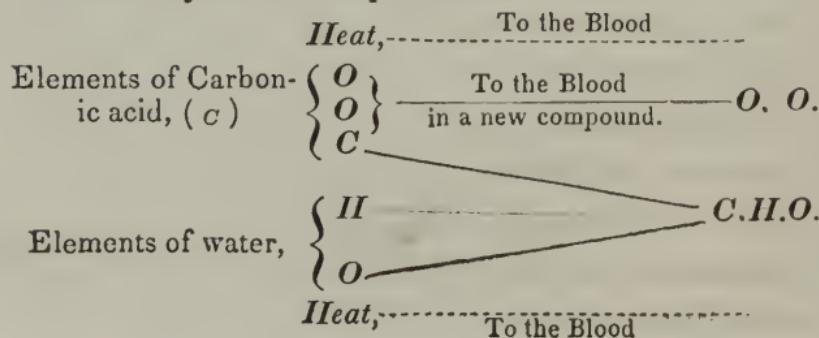
As fluid and gaseous substances, like water and Carbonic acid, on becoming solid must part with latent heat, it hence follows that, wherever the capillaries form these atoms of Hydrate of Carbon, latent heat must be set free, and thus furnish an incessant supply of this life-imparting agent.

*§ 45. Analogy and difference of vegetable and animal life.*

The *latent heat* set free in forming solid Hydrate of Carbon, (*C H O*) in animals, may be illustrated by recurrence to the Diagram for illustrating the decomposition of Carbonic acid by vegetables. [See § 31.] This will also show the difference, as well as strict analogy, between vegetables and animals, in forming this triple compound.

DIAGRAM 4.

In the systemic capillaries,



In vegetables, the heat of the Carbon and water converts the Oxygen of the Carbonic acid into atmospheric Oxygen *gas*. [§ 31, *Diag. 3.*] In animals, the heat of the Carbon and water are both set free in the blood, because the Oxygen is *not* converted into and thrown off as a *gas*.

Casting the eye upon the Diagram, it shows that in this formation the Oxygen of the Carbonic acid is thrown to the atmosphere while it is retained in the system of animals. To dispose of this surplus Oxygen in animals, has proved a difficult problem. It was at first surmised that it was in some way connected with the decomposition of muriatic acid, the Oxygen of the Carbonic acid uniting with the Hydrogen of the acid, to form water; a hypothesis surrendered in view of facts to be hereafter noticed.

Physiologists have demonstrated that the surface of the body, as well as the lungs, is constantly evolving Carbonic acid *gas*; and this fact accounts alike for the *aqueous discharges occurring from both pulmonic and cutaneous surfaces, in the form of an insensible vapor*. It also shows what ample provision the Archi-

tect of our bodies has made for the elimination of this effete Carbon, and aids our other proofs of the high importance of this function of the skin and lungs.

§ VI. HARMONY OF VITAL AND INORGANIC CHEMISTRY IN NATURE.

§ 46. *Harmony of all the Capillaries in Calorification.*

This view accounts for the universal diffusion of heat wherever red blood circulates, and connects by indissoluble links the cutaneous, respiratory and calorific functions ; the *interior capillaries of the body antagonising those exterior*, in the *formation and combustion* of Hydrate of Carbon ; and yet all *unite as one harmonious whole* in imparting heat to the swift currents of the vital fluids.

§ 47. *Harmony of vital and inorganic affinities.*

Controlled by the vitality infused into both sets of capillaries by the function of innervation, the laws of their vital chemistry and consequent animal heat are hence strictly accordant with the Chemical laws of inorganic nature.

§ 48. *Regulation of animal temperature.*

Thus far we have confined our inquiries to

the question, *how heat is generated*. But a word upon the *regulation* of animal temperature seems to be here demanded.

Like the chemico-vital office of generating heat, its regulation is obviously dependent upon the life-imparting influence infused into the capillaries at every point of the organism, by the nervous filaments, all uniting in the universal function, both of generating and regulating animal heat. While the nerves and capillaries are the vital agents, water is the great instrument of this function of graduating animal temperature. Moreover, water performs a most important part in all the vital and chemical phenomena of animated nature ; for it is not only in its simple but compound state, the great solvent of the nutrient elements, for repairing and building up the various tissues ; but is the medium for suspending, conveying, and, by its elements, forming the Hydrate of Carbon ; while it also carries off the other waste matters by the excretory outlets.

§ 49. It follows, as a deduction from the views I have presented, that the degree of animal temperature, *cæteris paribus*, in each class of animals, should bear a direct ratio to the ex-

tent of the pulmonary apparatus, as compared with the bulk of their bodies. This deduction is fully sustained by Dunglinson, Muller, and, indeed, by every physiologist.

*§ 50. Heat also proportionate to amount of Carbonic acid evolved.*

It must also be obvious that the degree of heat in animals would be proportionate to the amount of Carbonic acid evolved, as compared with the bulk of their bodies; a fact fully sustained by the rigid experiments and observation of modern physiologists. These conclusions are also fully borne out by other facts from comparative anatomy and physiology.

In cold-blooded animals, there is but a comparatively slight apparatus for the decarbonization of the blood; a fact readily explicable upon these physiological views, as there is little necessity for the decomposition of Carbonic acid, for the elevation of animal temperature, and, of course, no necessity for an extensive decarbonizing apparatus. In birds, on the contrary, the pulmonic apparatus is, comparatively, very extensive, occupying a large proportion of their bodies, and we find their temperature above that of man and the other animals of the

same class, and they give off nineteen times more Carbonic acid gas than the cold-blooded animals. (*Muller.*)

This elevation of temperature in birds, appears to be a provision of nature for expanding the gases extensively distributed in their cellular and pulmonary structures, and by adding to their specific levity, facilitating their accustomed movements. In the polar fox, the heat of whose body is at  $106^{\circ}$  or  $7^{\circ}$ , the lungs are very capacious.

These facts appear most fully to prove, that the evolution of animal heat is, in some way, dependent upon the office of the lungs; physiologists formerly supposed, directly so; but modern investigations, while they appear to disprove any direct connection, have failed to illustrate, as I have assumed to do, not only the direct, but the indirect, yet indissoluble links, uniting the functions of the cutaneous and respiratory surfaces, with the interior and universal generation of caloric.

§ 51. An explanation of the spontaneous combustion of the body in habitual drunkards, may be founded upon these physiological views. The experiments of Beaumont conclusively show that both water and alcohol are promptly

absorbed from the stomach. Alcohol has often been found distilled into the closed cavities of the brain, instead of passing off by the lungs, the usual safety-valve.

These, and various other facts, prove that alcohol may enter the blood without decomposition. From long habit of drinking, the blood becomes surcharged with this inflammable poison, as the breath indicates, even when the drunkard is most sober. This poison deranges all the functions of life, and if the lungs failed to throw off all the Hydrate of Carbon, and still absorbed Oxygen, as they constantly do, the blood having both Hydrate of Carbon and alcohol as inflammables, the Oxygen might ignite the Carbon and alcohol, and thus set up a spontaneous combustion in every part of the body where red blood circulates.

§ 52. It will be perceived that I have assigned to the lungs and surface of the body similar offices, the expulsion of Carbon and other excretal matters; while it is to the deeper seated, red capillaries, that the function of calorification is mainly assigned. It is in those capillaries carrying red blood that the decomposition of Carbonic acid takes place, while the serous capillaries are engaged in the more

elaborate office of depositing the nutritious elements which build up and repair the waste of our bodies, and which also furnish the materials for secretion. While in the lungs there are two sets of capillaries, the *systemic* for *nutrition*, and the *pulmonic* for *decarbonization*, so of the systemic we also find, upon these views, the same double set of capillaries, to wit: the *serous* for *nutrition*, and the *red*, or *carbonizing capillaries*, for *calorification*.

§ 53. *General summary of the first two Lectures.*

The following *summary* may be presented upon the reciprocal chemical changes of the blood in the capillaries of the lungs and system, and the *connection* of respiration with calorification:

1. The lungs perform an excretal office on which life constantly depends, because directly and indirectly aiding calorification.
2. The substance thrown off is Hydrate of Carbon.
3. The Carbon, on coming in contact with atmospheric Oxygen combines with it, forming Carbonic acid gas, which is thrown off from the lungs and skin by expiration and perspiration.
4. The amount of latent heat of the Oxygen

gas employed, is much greater than that of the Carbonic acid gas formed in the lungs, and, hence, caloric is set free, imparting heat to the blood and surface.

5. This free heat also combines with the water of the Hydrate of Carbon, and converts it into vapor.

6. The lungs and cutaneous surface aid in regulating animal temperature by the conversion of water into vapor, thus conveying off any excess of free caloric in the system by combining with it in the form of latent heat.

7. The water of the Hydrate of Carbon is converted into vapor in the lungs and upon the surface, precisely as when wood is burned, and hence assumes the form of insensible respiratory and perspiratory transpiration.

8. Facts appear to show that the chemical change in both venous and arterial blood may occur, independent of the vital principle, by applying to the venous, Oxygen gas, and to the arterial, Carbonic acid gas.

9. The systemic red capillaries are the antagonists of the pulmonary, and are constantly decomposing Carbonic acid, and, with water, forming Hydrate of Carbon ; or, in other words, carbonizing the blood.

10. From this union, water and Carbonic acid are transformed into a solid substance, and, hence, latent, becomes free heat, at every point where red blood circulates.

11. The function of the systemic red capillaries of the body in *decomposing*, and that of the small vessels of the lungs and skin in *recomposing* Carbonic acid gas, reciprocally depend upon and *balance* each other; in other words, one set *carbonizes*, the other *decarbonizes* the blood.

12. In consequence of this indissoluble link which connects the functions of respiration and calorification, the degree of temperature, the Carbonic acid evolved, and the size of the lungs as compared with the bodies of animals, always bear a direct ratio to each other.

13. There is a beautiful analogy between animals and vegetables, in the decomposition of Carbonic acid by the minute vessels of each.

14. This explanation shows that the great end and function of respiration is, both *directly* and *indirectly*, to aid in the all-important office of the generation and diffusion of animal heat.

15. The undetermined questions left in closing our last Lecture (§ 21.3,4,) have been settled by proving, *first*, that the coloring pigment

of venous blood is not elemental Carbon, but *second*, is a compound of Carbon and water.

#### § 54. *Unsettled questions.*

While the foregoing summary appear to be legitimate deductions, to be henceforward treated as physiological facts, it seems also proper, as in closing my last lecture, (Lec. 1.) to state what we have left unaccomplished.

16. The new compound into which the Oxygen of the Carbonic acid enters, remains to be investigated ;

17. Whether it be free Carbonic acid decomposed by the systemic capillaries ; or is derived from some compound containing it ;

18. Whether the Carbonic acid passes through the organism *unchanged* to be cast off from the lungs ; or is *formed* by some vital process ;

19. Whether the elements of water, which enter into the Hydrate of Carbon, are taken from the free water of the blood, or are derived from some compound of water ; or

20. Whether the elements of the water are taken from different compounds containing such elements, when these are combined with the Carbon.

In our inquiries thus far, I have attempted to

give you a birds-eye view of the organs of respiration, of their important offices in the animal economy, and of the links which connect them with the nervous and circulating systems, and with the function of calorification.

No rational mind that understands and contemplates this complicated piece of mechanism in its infinity of movements, can fail of being filled with admiration at the silver cords, which unite respiration with the other vital functions; or be less mindful of the unrivalled symmetry, and wonderful adaptation of all, to the great purposes for which they were created. Nor can we be less impressed with the important part carbonic acid plays, in the wide range of nature's operations. In the mineral kingdom, the important element of this substance is separated from the organic remains of vegetables which are transformed by a slow but unfaltering process, into the extensive coal mines found in the bosom of the earth. So on the deep foundation of the soundless Ocean, by vital insect chemistry combining Carbonic acid with lime, and by insect labor placing upon each rising summit, successive layers of this compound, there is begun and consecutively reared the coral island, till slowly lifting its

spray-capped head, it proudly towers above the mountain wave.

In the vegetable kingdom, by the decomposition of this gas and the deposit of its atoms, it forms the growing substance of every plant, from the humble violet, spreading its ephemeral beauties to the sunbeam, to the lofty oak bearing its arms and defying, for centuries, the howling blast, and raging tempest ; while in the animal creation, the same carbonaceous gas, by its rapid compositions and decompositions, imparts to all the vivifying stimulus of heat, alike spreading the wing of the insect, and aiding the eagle in his lofty flight ; alike rousing the glow-worm from his humble bed, and feeding the lamp of life in man, and lighting up the fire of genius. In contemplating the all-pervading influence of this agent, the conviction is strongly forced upon the mind, that the unseen Hand that guides its affinities,

“ Acts by general, not by partial laws.”

And, however humble have yet been the efforts of mind in unraveling the mysteries of its own “ fearfully and wonderfully made,” but frail earthly tenement, sufficient is already known to justify the conclusion, that the laws which con-

trol the rapid compositions and decompositions among the elements of animated beings, are as general and immutable as those stamped by the hand of Omnipotence upon the atomic changes of inanimate nature, or upon the cycling movements of the planetary system.

# LECTURE III.

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## OF OTHER CHEMICO-VITAL CHANGES CONNECTED WITH RESPIRATION AND CALORIFICATION.

### CHAPTER V.

§ 55. *Of the source of the Carbonic acid, and disposition of its Oxygen by the systemic capillaries.*

Questions to be answered: Whence the Carbonic acid for forming the Hydrate of Carbon? Whence its Carbon? Whence its Oxygen? How is the Oxygen disposed of?

§ 56. *Source of Carbonic acid; first views.*

In my last Lecture, I stated that Carbonic acid gas is an all-pervading compound in nature; that all water we drink contains it; that it is an ingredient of both arterial and venous

blood; that it is combined with the alkalies and other compounds of venous blood; and hence, that from some, or all these sources, sufficient Carbonic acid might be perpetually supplied for decomposition in the systemic capillaries, to furnish Carbon for the Hydrate of Carbon. These were, briefly, my first views on this point; they have for several successive years been presented in this form to the Medicinal Classes; and I have again presented them in like form for the purpose of examining them more critically than heretofore, and if wrong, to show how errors should always be corrected in such inquiries. We are always prone to take wrong roads in such investigations, and well settled facts should always be the guides to aid us back, and put us again on the right track.

*§ 57. Sources of Carbonic acid; corrected views.*

The sources already indicated for the needful and incessant supply of Carbonic acid for the formation of Hydrate of Carbon, are obviously reducible to the water and the food we swallow. Are these sources sufficient to furnish twelve ounces of Carbon from the Carbonic acid gas thrown off from lungs and skin in

twenty-four hours ; such amount being well settled as a physiological fact. This Carbonic acid must be either supplied already formed, or be manufactured in the animal body, while its elements, if previously uncombined, must be perpetually supplied from the food and drinks, to preserve the balance of waste and supply. The supply of Carbon must hence be equal to the pulmonic and cutaneous waste, or soon leave the lungs nothing to do in their function of decarbonizing the blood.

*§ 58. Free Carbonic acid in the food and drink insufficient to supply the pulmonic waste.*

It being clear that all the Carbonic acid, or its Carbon used in the systemic capillaries to form Hydrate of Carbon, must come from our food and drink, let us inquire whether these contain sufficient free Carbonic acid to furnish the supply. The sum of our drinks in twenty-four hours can by no means be sufficiently charged with Carbonic acid to supply any thing like the needful amount, because many gallons if not barrels of water, would be needed for the purpose. The solid food usually contains but a small amount of Carbonic acid, while it abounds in Carbon. We must hence believe that the sources of Carbonic acid first named,

(§ 56) are utterly inadequate to the requisite supply, and that the Carbon of the food must be somewhere in the organism oxydised by a chemico-vital process, before it is used to form Hydrate of Carbon.

### § 59. *Disposition of the Oxygen.*

But before we attempt to show where this oxydation occurs, let us try to clear up a difficulty which, for a long time, beset our inquiries, viz: the disposition of the Oxygen of the Carbonic acid. (§ 45.) In vegetables, as I have before explained, the Carbon unites with the elements of water to form the Hydrate of Carbon, while the Oxygen is thrown to the atmosphere. (See § 45.) When the Hydrate of Carbon is formed in the systemic capillaries of animals, it must, as when formed in vegetables, part with its Oxygen. It was at first surmised that the disposition of the Oxygen was connected with the decomposition of Muriatic acid, the Hydrogen of which united with this surplus Oxygen to form water.

This surmise was surrendered in view of these facts: (1.) That free muriatic acid does not exist in the blood; (2.) That if it did, its decomposition would set chlorine free in the

circulating mass, and thus prove a suddenly fatal agent, unless simultaneously entering into some new combination as the antidote; and (3.) that no such combination could be explained upon any known facts and laws of organic or inorganic chemistry. That Oxygen gas is not thrown off from animals as from the leaves of vegetables, is a fact well determined. This surplus Oxygen must hence, obviously, unite in some new solid or fluid form.

§ 60. *With what does the Oxygen unite?*

Some well known facts stated by Liebig, seem to show that this surplus Oxygen unites with the Oxide of Iron, which is always a constituent of the red globules of blood. He remarks, "The globules of blood contain a compound of iron. From the never-failing presence of iron in red blood, we must conclude that is unquestionably necessary to animal life."

To this remark of Liebig all will subscribe. Oxide of Iron, though a constituent of vegetables, is not contained in their sap or circulating fluids, while it is found in the fluids, or blood of animals. From these facts, it appears fair to infer, that the Oxide of Iron in the blood of animals is employed in aid of some functions

not found in vegetables, and that, hence, it may probably be connected with the functions of respiration and calorification.

Liebig has the further remarks, that “the compound of iron in the globules of blood has the characters of an oxydized compound;” that “no other metal can be compared with iron for the remarkable properties of its compounds;” and adds, “the compounds of protoxide of iron possess the property of depriving other oxydized compounds of Oxygen; while the peroxide of iron, under other circumstances, gives up Oxygen with the utmost facility.”

Admit that the protoxide of iron exists in the blood, it might readily absorb the Oxygen given off from the Carbonic acid decomposed in forming the Hydrate of Carbon, and thus convert the iron into the peroxide. The peroxide thus formed, would be carried along in the circulation from the systemic to the pulmonic capillaries. But the same difficulty would be encountered in the lungs as in disposing of the surplus Oxygen of the Carbonic acid in forming Hydrate of Carbon, while it would leave the source of Carbonic acid undetermined.

§ 61. *Source of Carbonic acid: Law of iron.*

A fact, or *law*, as stated by Liebig, will not only show the source of supply of Carbonic acid for forming the Hydrate of Carbon, but will also enable us to dispose of this surplus Oxygen,—the two objects of this part of our inquiry, (§ 55.) He says: “Carbonate of protoxide of iron, in contact with water and Oxygen, is decomposed; all the Carbonic acid is given off, and by absorption of Oxygen it passes into the Hydrated peroxide, which may again be converted into a compound of the protoxide.”

The existence, however, of this compound of iron in the blood is by no means established.

§ 62. HYPOTHESIS: *Protoxide and Carbonate of Protoxide of Iron in blood.*

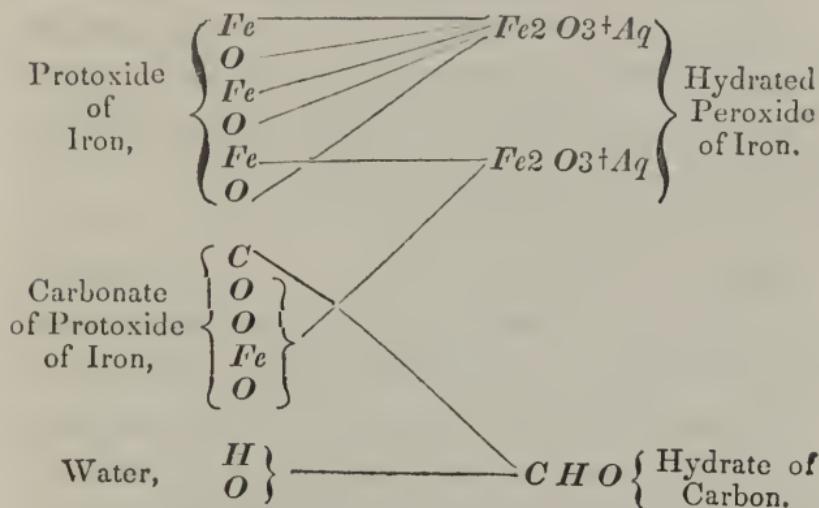
But let us admit as hypothesis, to be afterward proved as fact, that arterial blood contains protoxide and *Carbonate of the protoxide of iron*. If the laws of vital chemistry in the systemic capillaries are the same as those of inorganic chemistry just stated, the following must be the results:

The blood always contains *water*. The Carbonic acid itself contains *Oxygen*, and these two conditions of the law quoted (the presence of water and Oxygen,) existing, the Carbonate of the protoxide of iron would be resolved into

the Hydrated peroxide, and the Carbonic acid *set free* to combine in a new form. Carbonic acid out of the body darkens arterial blood, and it must do so in the systemic capillaries. But what chemical changes occur? The following diagram will illustrate :

DIAGRAM 5.

§ 63. Showing the formation of the hydrated Peroxide of Iron, and of the Hydrate of Carbon, in the systemic capillaries :



The Carbon (C.) of the Carbonic acid goes to unite with the elements of water to form Hydrate of Carbon. The Oxygen of the Carbonic acid passes to the protoxide of iron to convert it into the peroxide. The peroxide unites with

the water of the blood, and thus becomes **Hydrated peroxide**.

We have thus deoxydised the blood through the instrumentality of the **Oxides of Iron**, and furnished the **Carbonic acid**. This completes the circle of affinities in forming **Hydrate of Carbon** for calorification ; but it has been done by assuming as hypothesis that the **protoxides** and **Carbonate** of **protoxide of iron** are constituents of blood. The elements of water are also used in the diagram *hypothetically*, without previously settling the question whether the water of the blood is taken to form **Hydrate of Carbon**, or whether its elements are derived from other compounds containing them. The **Hydrated peroxide** of iron formed upon this hypothesis, would, obviously, go on in the circulation from the systemic to the pulmonic capillaries ; but the **protoxide of iron** must obviously have been sent through the arteries from the lungs. Let us therefore follow the track of the arteries back to the pulmonic organs, and see if these, in completing **hæmatosis**, furnish the compounds of iron supposed..

## CHAPTER VI.

§ 64. *Of the chemico-vital changes produced by the lungs as an organ of haematosis.*

Questions to be answered. What the primary source of the per and protoxides of iron ? What the source of Carbonate of protoxide of iron ?

The chemico-vital laws thus far determined show, that if Carbonate of protoxide and protoxide of iron are constituents of arterial blood, the peroxide must necessarily be formed in the systemic capillaries in the function of calorification. The Hydrated peroxide of iron so formed in the systemic capillaries, upon our hypothesis, (§ 62,) was sent via the veins to the lungs ; but the pre-existence of this Oxide of Iron in the blood does not rest upon the hypothesis assumed, (§ 62.) It is next proposed to show, not only the pre-existence of the peroxide of iron in blood ; but, that the other two forms of iron assumed in the hypothesis, (§ 62,) as constituents of arterial blood, must both be formed by the capillary chemistry of the lungs. This done, it will show the protoxide of iron on the one hand, and the hydrated

peroxide on the other, reciprocally dependent upon and balancing each other in their formation respectively by the pulmonic and systemic capillaries, and in oxidizing and deoxidizing Carbon for calorification. Recurrence to the facts of the indefatigable Liebig, show peroxide of iron to be a constituent of blood. He states that "the compound of iron in the globules has the characters of an oxidized compound; for it is decomposed by sulphuretted hydrogen exactly in the same way as oxides, or other analagous compounds of iron. By means of diluted mineral acids, peroxide (sesquioxide) of iron may be extracted, at the ordinary temperature, from the fresh or dried coloring matter of the blood."

[The manner in which the Hydrated peroxide of iron in the blood is formed by the capillaries of the lungs, from the elements sent from the stomach, will be hereafter explained.]

If from the fact that Hydrated peroxide of iron exists in blood, and from the law of its affinities, that "*Hydrated peroxide of iron in contact with organic matters, destitute of sulphur, is converted into the Carbonate of protoxide,*" (Liebig,) we can show the formation of protoxide and Carbonate of protoxide of

iron by the pulmonic capillaries, the chemico-vital changes of the systemic capillaries for calorification, as explained by the hypothesis, (§ 62,) will be fully established.

§ 65. *Hydrated peroxide of iron decomposes chyle and blood.*

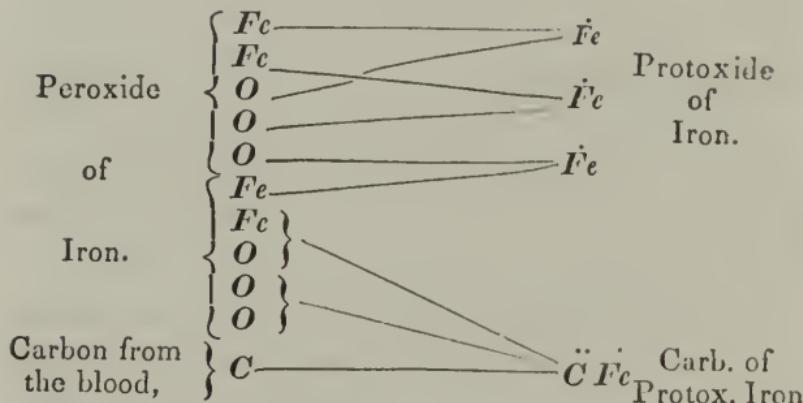
Let us apply this law to the vital changes produced by the lungs upon the elements of blood. The chylous fluids, after their perfection in the apparatus for their formation, and their entry into the left subclavian vein, pass through, as the first set of capillaries,—those of the lungs. The chylous fluids are, obviously, not only *organic matters*, but they are in the best possible condition of minute subdivision to facilitate chemical change. The same principle holds true as to the debris of the tissues, or any other constituents of blood. It cannot be reasonably doubted that the Hydrated peroxide of iron would act in, as out of the body, on being brought in contact in the pulmonic capillaries with the chylous fluids and other constituents of blood. If so, the blood would be decarbonised, the Carbon would be oxidised by the surplus Oxygen of the Hydrated peroxide of iron, and this would thus be

converted into the Carbonate of protoxide by union with the Carbonic acid formed. The formation of the Carbonate of protoxide in the pulmonic capillaries, must hence be a physiological truth.

§ 66. *Diagram. Protopxide and Carbonate of prototxide of iron formed by the pulmonic capillaries.*

This fact may be thus illustrated :

DIAGRAM 6.



The Oxygen of the peroxide of iron oxidises the Carbon of the nutritive fluids ; the Carbonic acid and prototxide of iron thus formed, unite as the Carbonate of prototxide. Moreover, there is formed not only the equivalent of prototxide in union with Carbonic acid, but three other equivalents of simple prototxide are

formed to go out from the lungs in arterial blood. This fully verifies the facts assumed in the hypothesis, (§ 62,) and as displayed by the diagram for illustration, (§ 63.)

The truth of the explanation of chemical changes produced by the vital action of the systemic capillaries for calorification is hence established, and the circle of affinities performed by iron in calorification, is fully displayed.

§ 67. *Summary. Deductions from the facts examined.*

The lungs are not only employed in the functions of *excretion* and *calorification* in expelling and oxidizing the Carbon of the Hydrate of Carbon, but are the last of the organs of *haematosis*, viz :

1. In decarbonizing the chylous and other constituents of blood, thus fitting them for nutrition.

2. This decarbonization of the elements originally entering the animal as food, furnishes the Carbon of Carbonic acid, and the Hydrate of Carbon employed in the function of calorification.

3. That the Oxides of Iron are the first instruments for oxidizing and deoxidizing Carbon as the important agent in calorification,

while atmospheric Oxygen is the last agent.

4. The protoxide of iron is the carrier of the carbonic acid from the lungs to the systemic capillaries.

5. The affinities of the iron in its circle for calorification show, that if either Oxide exists as a constituent of blood, the other Oxide must necessarily be formed ;—the *pulmonic* and *systemic* capillaries antagonizing and balancing each other, in *oxidizing* and *deoxidizing* these compounds.

§ 68. While the foregoing deductions fully answer the first four questions stated as the objects of inquiry in this lecture, the primary source of the iron and its oxides remains unexplained, as does the inquiry “ whence the elements of water in the Hydrate of Carbon.” That both find their way into the blood from the stomach, is obvious. But what chemico-vital changes their elements undergo in reaching their points of destination in the organism as the aids of the functions of *respiration* and *calorification*, should be determined before our circle of vital affinities can be considered as complete. Preliminary to doing this, however, it is necessary to consider,

## CHAPTER VII.,

## THE CHEMICO-VITAL RELATIONS OF THE PULMONIC AND GASTRIC FUNCTIONS.

§ 70. It will be remembered that I stated, as my first surmise for disposing of the Carbonic acid in the formation of the Hydrate of Carbon, that the change was connected with the decomposition of muriatic acid. Upon this hypothesis, the surplus Oxygen would combine with the Hydrogen of the muriatic, or Hydrochloric acid, to form water. This hypothesis was surrendered for reasons already given, (§ 59.)

Although this disposition of the Oxygen proved an untenable hypothesis, we are now to attempt the proof that the formation of the Hydrate of Carbon by the systemic capillaries is *indirectly*, but *remotely*, connected with the formation of muriatic acid by the capillaries of the stomach. It is an admitted fact in physiology, that the muriatic acid is the essential solvent of the gastric juice, but the strict analogy between the vital chemistry of the capillaries of the stomach, in secretion, and some of

the chemical changes of inorganic nature, seems never to have occurred to physiologists. The examination of a few facts will illustrate this analogy.

It is a well known fact that animals soon die, unless supplied with salt, which is the only extensive ingredient of blood containing chlorine. Neither do animals live long if entirely deprived of water. Salt is a compound of chlorine and sodium. Muriatic acid is composed of hydrogen and chlorine, and hence the more modern designation is Hydrochloric acid. Soda is a compound of Sodium and Oxygen, and is an ingredient of blood, while muriatic acid is not. As muriatic acid constitutes the active solvent of the gastric fluid, and as it does not exist in a free state in blood, the muriatic acid of the gastric juice cannot be an educt from blood, but must be formed from the chemical transformation of some compounds containing its elements ; because animal chemistry *creates* no new elements.

Leibig says : "The presence of free muriatic acid in the stomach, and that of soda in the blood, prove beyond all doubt the necessity of common salt for the organic processes ;"

but how salt is transformed into muriatic acid, this able chemist and physiologist has failed to explain. This shows that he was led to the very threshold of the explanation of gastric secretion, I am now to offer.

*§ 71. Muriatic acid of the gastric solvent; how formed.*

It is proposed to determine at what point of the organism this chemico-vital process occurs; and also show its strict analogy to a process of inorganic chemistry. Upon careful examination of the chemical compounds of the blood, it will be found that the two elements of muriatic acid can only be derived from common salt and water; and hence the free muriatic acid secreted by the stomach, must be formed by the union of the chlorine of salt and the hydrogen of water. This would leave the Oxygen of the water and the sodium of the salt to unite, and the compound would be oxide of sodium, or free soda. *There is consequently double decomposition between the elements of water and salt in the capillaries which secrete the gastric fluid.*

*§ 72. What analogy to inorganic chemistry?*

On applying the galvanic apparatus to a solution of salt and water, double decomposition occurs; the chlorine of the salt unites with the

hydrogen of water, forming muriatic acid ; (*H Cl.*) while the union of the Oxygen of the water and sodium of the salt forms free soda. Although most obvious that the nervous apparatus and intimate nervous filaments which preside over the organic action of capillary gastric secretion, perform in this vital process the very same double decomposition as the galvanic trough, I will not stop to insist that the proximate cause of this change is alike electric in both, although apparently sustained by the artificial digestion performed by exposing food to the influence of salt and animal membranes, connected with the galvanic apparatus.

*§ 73. But what becomes of the soda manufactured by the gastric capillaries ?*

The soda does not enter the interior of the stomach for digestion, as does the muriatic acid, and it must hence pass on in the gastric veins. This would supply the free soda found upon analysis in the blood, as also this important element of bile. A fact stated by all physiologists is, that bile is rapidly secreted during the digestion of a meal, while the liver is nearly quiescent in the intervals. Precisely the same with the stomach, which, according to Beaumont, generally secretes gastric juice only while

a meal is digesting, when rapid secretion occurs. As the soda formed, constitutes an important ingredient of both bile and blood, let us inquire by what avenues does it reach the heart and liver? Evidently through the veins of the stomach.

*§ 74. But where do these empty?*

The veins of the stomach help make up the vena porta, which goes to the liver. Part of the soda formed by the capillaries of the stomach would therefore be used in the secretion of the bile, of which soda is an important element; while the residue would pass directly through the vena cava hepatica into the general mass of blood, and supply it with its free soda. This explanation connects, by indissoluble chemico-vital links, the functions of the stomach and liver, soda being manufactured by the stomach for the secretion of the bile at the very time needed to complete digestion. This physical union of the stomach and liver fully accounts for the rapid secretion of both organs during the digestive process, and their simultaneous quiescence in the intervals of digestion.

In the intervals of meals, it must be evident that the salt and water of the blood pass unchanged through the vessels which secrete the

gastric juice ; but salt and water being natural constituents of blood, this intermittent action of the gastric vessels would by no means derange the organism. So in the liver, the portal blood would pass nearly or quite unchanged in the intervals of meals. The stimulus of a meal seems to rouse the nervous influence imparted to the capillaries of the stomach and liver, inducing their respective secretions.

§ 75. *We have a striking analogy to this intermittent secretion of the stomach and liver, in vegetable physiology.*

The Carbonic acid, which constitutes a principal nutritive element for the growth of vegetables, is decomposed at one period of the day, while at another, it passes unchanged from their leaves. When the stimulus of the sun is imparted, the Carbon forms a union with water, forming *Hydrate of Carbon* for their growth, while the Oxygen is evolved from the leaves. Withdraw the sun's influence, and the carbonic acid passes off unchanged, thus cutting off this important source of their nutrition, until the sun again imparts its life-infusing stimulus. This is beautifully illustrated by water vegetables under ice. When the sun's influence is withdrawn, bubbles of Carbonic acid

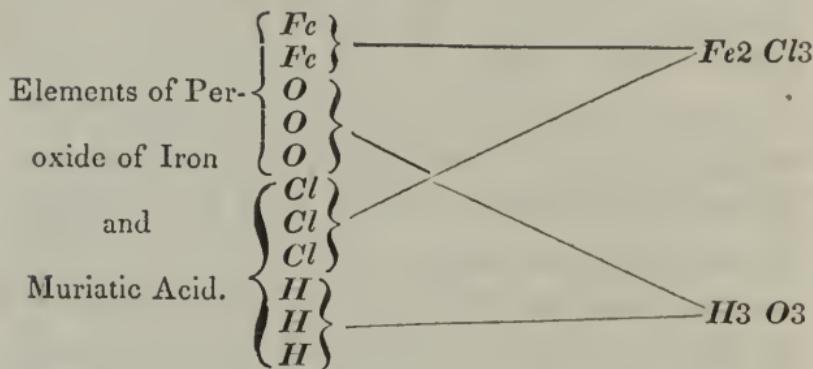
gas collect under the ice ; when the sun shines, bubbles of Oxygen gas rise in like manner.

### § 76. *Source of iron in the blood.*

That peroxide of iron is a constituent of the red globules of blood is proved by the most careful analyses, and hence our reasonings heretofore founded upon this fact are legitimate. But while this is an admitted fact in organic chemistry, the chemico-vital process, which forms this constituent of blood, has never been explained. This I shall now attempt, by showing the relation between the stomach and lungs as the first and last organs for the formation of blood in the function of haemato-sis. That the oxides of iron are the essential coloring ingredients of the red globules, is the general belief of physiologists and chemists. It must, obviously, be in the minutest state of subdivision ; these minute solid atoms being mechanically suspended by the adhesive properties of blood. The oxide of iron is found as a constituent of vegetable and animal food, and being a solid, and insoluble in water, it is plain that it must be rendered soluble by digestion before it can be absorbed by the lacteals. Its not coloring the chylous fluids, is an evidence that it has united with some other element.

According to Beck, peroxide of iron digested in muriatic acid, forms the perchloride. This acid being the active solvent of the stomach, must form there the same soluble compound of iron; thus:

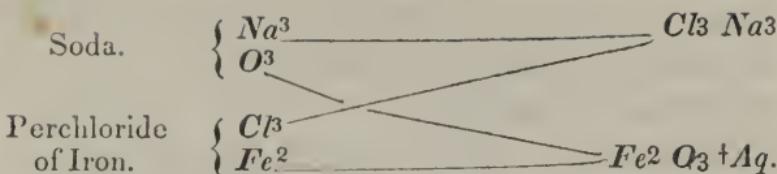
DIAGRAM 7.



The chloride of iron thus formed passes in colorless solution with water, through the lac-teals into the blood.

§ 76†. After the lacteals, the next capillaries through which the chyle has to pass, are those of the lungs. The perchloride of iron decomposes the free soda, the sodium combining with the chlorine to form salt, and the Oxygen with the iron, which with the water of the blood, forms hydrated peroxide of iron, the very compound needed in the lungs to decarbonize the nutritive fluids, as before proved; thus:

## DIAGRAM 8.

§ 77. *Red globule completed.*

This diagram will readily call to mind the facts, that the salt and water are decomposed in the stomach, forming muriatic acid and soda, which thence take different directions. The soda travels via the liver and heart, to form the free soda of the blood, while the muriatic acid goes as the carrier of the iron, and the two again meet in the pulmonic capillaries. Usual affinities being here restored, would form the *hydrated peroxide of iron, and thus complete the red globule.* *The lungs are, hence, the last of the organs of haematosis.* This is the very point of the organism where we before proved, that the organic matters of chyle and blood were decarbonized, and the Carbon oxydized by the hydrated peroxide of iron to form the Carbonate of the protoxide.

§ 78. *The circle of affinities completed.*

We have traced all the connecting links of vital chemistry in the changes of the Carbon

and iron from the lungs, through each set of capillaries back to the stomach; thus completing the circle of affinities, which these important agents perform in heating the furnace of the living locomotive.

The answers to the unsettled questions at the head of the chapter, as to the source of the iron and its oxides in blood, may be briefly summed up—

1. The iron is originally derived from vegetables, in the form of oxide of iron.
2. This oxide of iron is converted into perchloride of iron by the muriatic acid of the gastric juice, and thus rendered soluble.
3. The perchloride of iron is reconverted in the lungs into the hydrated peroxide of iron by the free soda of the blood.
4. The hydrated peroxide is converted into the protoxide in the lungs, by oxydizing the Carbon of the nutritious fluids.
5. The protoxide carries Carbonic acid thus formed to the systemic capillaries for calorification, and is there reconverted into hydrated peroxide.
6. In the series of chemical compositions and decompositions of iron and Carbon, as explained, an exact balance is preserved in the amount

of each at all points of the organism where employed for calorification.

7. The oxides of iron are, *probably*, employed in *oxidizing* and *deoxidizing* various other compounds than those already considered, as

8. In deoxidizing sugar, &c., to form animal fat, and in oxidizing the Carbon of the fat for calorification.

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## CHAPTER VIII.

### OF THE CHEMICO-VITAL CONNECTION OF DIGESTION, HEPATIC SECRETION, CALORIFICATION AND NUTRITION.

Question still unsettled: Whence the water, or its elements, to form Hydrate of Carbon?

#### §79. *Soda, and its uses in bile.*

Having traced one portion of soda formed by the stomach, by a direct channel, through the vessels of the liver into the blood, let us follow the track of the other portion, which enters as an important element of bile, in its chemico-vital uses. In the hepatic secretion, soda forms one of the leading elements, and as soon

as bile enters the duodenum, it begins to part with its soda, which combines with albumen, forming a soluble compound in the serum of chyle and blood. The proportion, which this compound of soda and albumen bears to the other ingredients of chyle, goes on increasing in traversing the intestinal canal and lacteal apparatus, until it enters the left subclavian vein ; and the soda must hence attract the albumen from the other elements of the chyme.

It is an admitted physiological fact, that the soda remains the solvent of the albumen, not only in chyle, but in the mass of blood, until the albumen is needed for nutrition, secretion, or other vital uses in the systemic capillaries.

§ 80. *Of Muriatic acid as a carrier of nutritive elements.*

Having traced the soda used in bile, through the digestive apparatus, as a solvent and carrier of albumen into the blood, to fit it for nutrition in the systemic capillaries, let us go back to the stomach and follow the free muriatic acid of the gastric juice in its ultimate uses, as another carrier of nutritive elements. Besides the iron and albumen, as important elements of vegetable and animal food, as already noticed, the leading ones are fibrin and casein, which

are first formed by vegetables, and then transferred by the chemico-vital action of animals, and appropriated to building up their structure. The more essential elements, hence, of animals and vegetables are those named. It is obvious that all and every atom of nutriment, whether in form of iron, albumen, casein, fibrin, or other nutritive element, must be subjected to, and combined with, the gastric solvent to form the chyme, and disposed of in the manner explained in the function of haematosis. Physiology has furnished no evidence that the process of chylification has, at any point of its progress, separated the fibrin, casein, and other nutritive elements from their primary solvent in the stomach; and we may from this conclude, that when they reach the mass of blood in the left subclavian vein, they continue soluble from their union with muriatic acid. The fibrin or casein so held in solution by muriatic acid, would go the round of the circulation to the systemic capillaries, to which point we have just followed and left its fellow carrier, Soda, still joined to albumen.

§ 81. *Nutrition, by re-formation of salt and water dropping albumen and fibrin.*

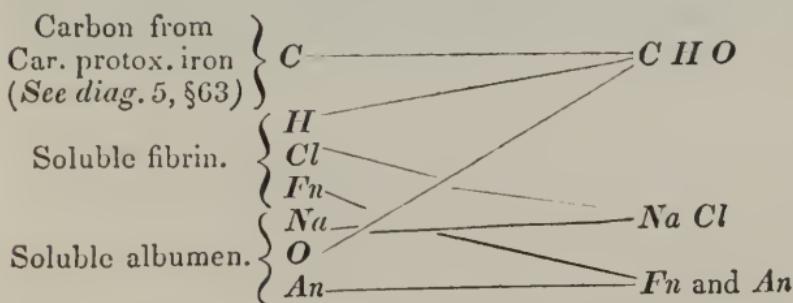
As the usual affinities of inorganic nature,

between the elements of salt and water, had been broken up by the vital chemistry of the stomach when the soda and muriatic acid started as carriers, it is obvious, if the elements of salt and water, which had been separated at the stomach, resume in the systemic cappillaries their usual affinities, the soda and muriatic acid, by a double decomposition, would reunite to form salt and water, and drop their albumen and fibrin, as molecular solids. This would, obviously, carry and drop the atoms of these essential elements of the animal structures at all points of the organism, to contribute to its growth, and to supply its waste. Now albumen being the animal element of the nervous system, and fibrin of the muscular; and these two systems being always intermingled in the intimate structures, and combined in the same functions, especially in those of motion, these two essential elements of their growth would be deposited side and side in the nervous and fibrous filaments. The salt and water thus formed, would proceed directly onward in the general mass of blood, carrying with them the refuse atoms displaced by the new, to be discharged by the kidneys and other excretory outlets. It will be perceived that the muriatic

acid and soda are, upon this physiological view, mere carriers of the nutritious particles from the stomach to the solids of the tissues; and that as soon as they have done this, they resume the affinities of inorganic chemistry, form salt and water, and become again carriers of the waste molecules out of the body. This deposition of nutritive elements must be at those points where the systemic capillary arteries terminate in the correspondent veins; the very points, as before shown, where calorification occurs from the formation of Hydrate of Carbon.

§ 82. Let us, by a Diagram, endeavor to answer the deferred question: "Whence the elements of water to form the Hydrate of Carbon?"

DIAGRAM 9.



The muriatic acid (HCl) of the soluble fibrin and the soda (NaO) of the soluble albu-

men react on each other, and, depositing fibrin (Fn) and albumen (An) for NUTRITION, form common salt (NaCl) and evolve Oxygen (O) and Hydrogen (H), the very elements of water (HO), which are required to convert the Carbon (C) into Hydrate of Carbon (CHO). (It will be remembered that water was assumed *hypothetically* in § 63.) This answers the reserved and last question, "Whence the elements of water to form the Hydrate of Carbon?"

We have now shown how are united by chemico-vital union, all the important functions of animal life, how each is reciprocally dependent upon every and all others, and how all are again balanced in one harmonious series of vital affinities by the function of innervation. This series may now be presented in the order of nature by a brief *synopsis* of the more important conclusions from our inquiries.

# LECTURE IV.

GENERAL SUMMARY AND INFERENCES FROM PRECEDING LECTURES.

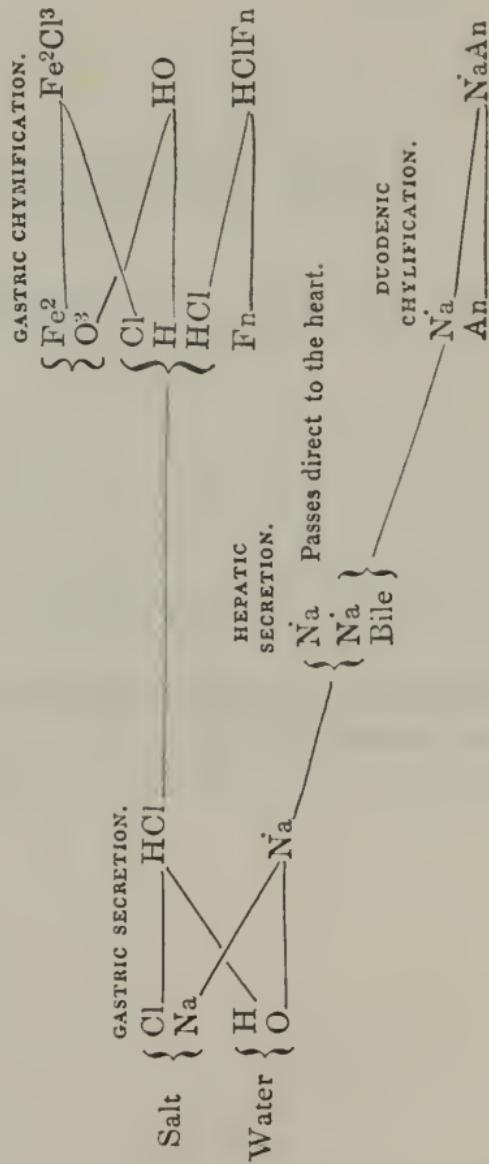
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## CHAPTER IX.

SYNOPSIS OF THE CIRCLE OF CHEMICAL CHANGES IN ANIMAL LIFE.

## CIRCLE OF VITAL AFFINITIES.

DIAGRAM 10.  
*Gastric, hepatic and duodenic secretion and digestion.*



## DIAGRAM 10...EXPLANATION.

**GASTRIC SECRETION.**—Double decomposition of the *water* and *salt* is effected by the organism of the stomach, in a manner analogous to the action of electro-galvanism on the same compounds. In this decomposition the *oxygen* (O) of the water unites with the *sodium* (Na) of the *salt* to form *soda* (Na) : the *hydrogen* (H) of the *water* unites with the *chlorine* (Cl) of the *salt* to form (HCl) the *free muriatic acid* of the gastric secretion.

**GASTRIC CHYMIFICATION.**—*Free muriatic acid*, as a general solvent of the food, unites with *peroxide of iron*, (Fe<sub>2</sub>O<sup>3</sup>) one of the constituents of the food, and forms by double decomposition *water* (HO) and the *perchloride of iron* (Fe<sup>2</sup>Cl<sup>3</sup>). Another portion of the *muriatic acid* unites with *fibrin* (Fn) forming a soluble compound, (HClFn).

**HEPATIC SECRETION.**—The *soda* (Na) is carried to the liver by the gastric veins. A part goes thence, by the *vena cava hepatica*, to the heart : this is the *free soda* of the blood. Another part of the *soda* is incorporated with the bile.

**DUODENIC CHYLIFICATION.**—This *soda* of the bile, passing into the duodenum, unites with *albumen* (An) rendering it soluble (NaAn).

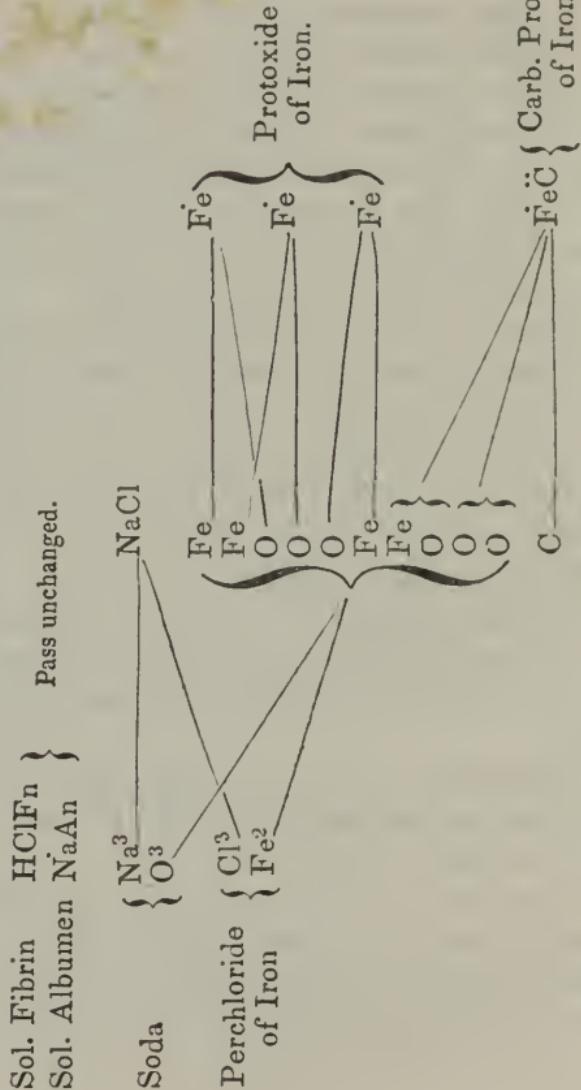
The various components of the chyle, *perchloride of iron* (Fe<sup>2</sup>Cl<sup>3</sup>), *water* (HO), *soluble fibrin* (HClFn), *soluble albumen* (NaAn), &c. pass by the lacteals and the left subclavian vein, through the heart, to the pulmonic capillaries.

## CIRCLE OF VITAL AFFINITIES.

## DIAGRAM 11.

*Pulmonic capillaries in the function of haematosis.*

Sol. Fibrin       $\text{HClFe}_n$       Pass unchanged.  
 Sol. Albumen  $\text{NaAn}$



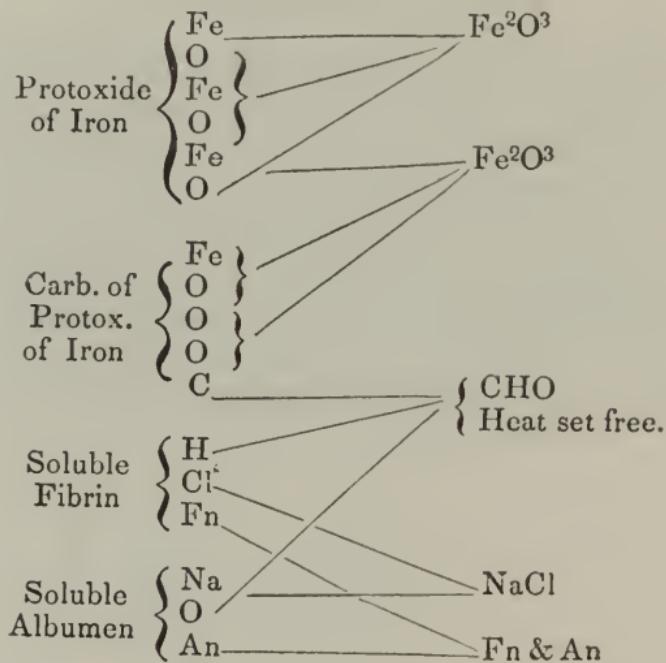
## DIAGRAM 11.--EXPLANATION.

*Soluble fibrin* ( $HClFn$ ) and *soluble albumen* ( $NaAn$ ) pass through the pulmonary capillaries unchanged. The free *soda* ( $Na$ ) of the blood and the *perchloride of iron* ( $Fe^2Cl^3$ ), by double decomposition, become *common salt* ( $NaCl$ ) and *peroxide of iron* ( $Fe^2O^3$ ); the latter, in contact with the carbonaceous compounds of the blood, is converted into *protoxide of iron* ( $Fe$ ) and *carbonate of protoxide of iron* ( $Fe\ddot{O}$ ). These pass on to the systemic capillaries together with the *soluble fibrin* and *albumen*.

## CIRCLE OF VITAL AFFINITIES.

## DIAGRAM 12.

*Systemic capillaries in the functions of calorification and nutrition.*



## DIAGRAM 12.--EXPLANATION.

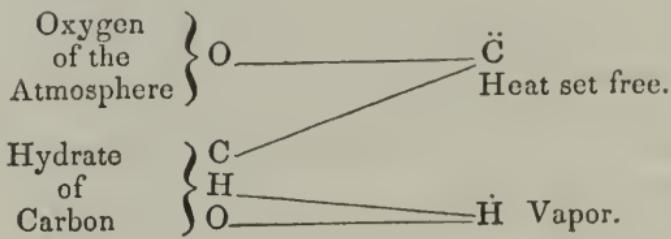
*Protoxide of iron (Fe)* and *carbonate of protoxide of iron (FeC)* are converted into the *peroxide of iron (Fe<sup>2</sup>O<sup>3</sup>)*, the *carbon (C)* being set at liberty. Double decomposition takes place between the *muriatic acid (HCl)* of the *soluble fibrin (HClFn)* and the *soda (Na)* of the *soluble albumen (NaOAn)*: the *elements of water (HO)* go to unite with the *carbon (C)*, set free from the *carbonate of protoxide of iron (FeC)*, to form *hydrate of carbon (CHO)*, while the *chlorine* and *sodium* form *common salt*, which, with other waste molecules, passes off from the system through the excretory organs. The *fibrin* and *albumen* are simultaneously deposited for **NUTRITION**.

The change of the *carbon* from *carbonic acid (C)* into the solid *hydrate of carbon (CHO)* gives rise to an evolution of heat; and this process, taking place at all points of the organism where red blood is converted into venous, produces **UNIVERSAL CALORIFICATION**.

## CIRCLE OF VITAL AFFINITIES.

## DIAGRAM 13.

*Pulmonic and cutaneous capillaries in the functions of excretion and calorification.*



## DIAGRAM 13.--EXPLANATION.

In the lungs and skin the *oxygen* (O) of the air, meeting with the *hydrate of carbon* (CHO), forms *carbonic acid* (C) and *watery vapor* (H), both of which pass off as **EXCRETIONS**.

As in burning wood, the formation of the same products is attended with the evolution of heat more than sufficient to disengage the *carbonic acid* and water in the æriform state, so from the lungs and skin the *carbonic acid* and *water* escape in the gaseous form and leave still a large surplus of heat to warm the passing currents of the blood and unite with the systemic capillaries in the function of **UNIVERSAL CALORIFICATION**.

## CHAPTER X.

## PHYSIOLOGICAL AND PATHOLOGICAL INFERENCES.

§ 87. *Coagulation explained.*

It has already been explained how the vital chemistry of the stomach overcomes the usual affinities of the elements of salt and water ; how the new formations, soda and muriatic acid, become the carriers of the new elements for calorification and nutrition ; and how the diversified processes of vitality use the elements carried by them to the organism, and how, by the restoration of the usual affinities of chlorine and sodium, salt and water are re-formed. It must be quite intelligible how fibrin, in union with muriatic acid, like iron so combined, may have its carrier taken from it by soda, whether this be united with albumen, or free in the blood. The fibrin may be employed separately from albumen when fibrin only is wanted in any organic process, by its muriatic acid uniting with the free soda of the blood. When death occurs, the rotary motion of the globules, observed during life, soon ceases, the control of vitality over chemical changes must also cease ;

the congregation is broken up, and each element finds its old associate in the wide world of inorganic nature. So, also, to arrest the vital fluid in a blood vessel, or to draw it from the body, suspending the usual rotary movements of its globules, breaks up the vital, and subjects it to inorganic affinities. While the albumen still remains dissolved in the serum, the soluble fibrin becomes solid; its muriatic acid combines with the free soda precisely as in the vital process just explained.

§ 88. *Probable function of the mesenteric glands.*

Soda is the solvent of albumen. That muriatic acid is the solvent of fibrin and other animal elements, has been drawn as a deduction from the facts noticed in the progress of our present inquiries, (§ 80.) Not only does this explain coagulation, but considered in connection with *two* facts noticed by physiologists, it seems to shed some light upon the hitherto undetermined function of the mesenteric glands.

*One* fact is, that fibrin is *decomposed* by muriatic acid. If so, the muriatic acid of the stomach should have a like effect in digestion.

*A second* fact is, that fibrin cannot be detected in chyle until this has passed the mesenteric

glands. The *first* fact would seem to show that the stomach must change the arrangement of the elements of fibrin; and the *second*, that the function of the mesenteric glands in restoring fibrin as a constituent of chyle, must be analagous to the function of vegetables in primarily forming fibrin from inorganic elements.

It would from these facts, considered in conjunction with that of coagulation, seem probable, that the function of the mesenteric glands may be to recombine the elements of fibrin decomposed by the stomach, and restore them to their primary arrangement, to be subsequently held in solution by the muriatic acid.

§89. *Is there free Carbonic acid in blood, both arterial and venous?*

The affirmative of the question is maintained by Muller, Carpenter, and numerous other physiologists of eminence. While coagulation is one of the prompt chemical changes of blood withdrawn from the vital influence, others still more prompt occur; such as the reddening of venous blood by oxygen, and the darkening of arterial, by Carbonic acid. It has been already shown that the very same chemical changes result from the application of these gases to arterial and venous blood *in*, as *out* of the

body, (§ 22.) If venous blood be acted upon by atmospheric air out of the body, the ignition of the Hydrate of Carbon produces Carbonic acid gas, and reddens it, as when passing the lungs. This may exhibit all the appearances of preexisting Carbonic acid in the blood. So of arterial blood ; the Carbonate of protoxide of iron formed by the function of haematosis in the lungs, if exposed out of the body to the influence of *oxygen*, would evolve the Carbonic acid, (§ 61) giving to the arterial blood all the appearance of containing free Carbonic acid.

From the well known affinity of free soda for Carbonic acid it seems fair to infer, that if this acid entered the blood vessels by the stomach, the two would at once *combine as Carbonate of soda* ; *thus accounting for this compound as a constituent of blood*. Moreover, facts show Carbonic acid gas to be a noxious agent in blood, as when absorbed in respiration. It may be objected that this result is produced by excluding Oxygen, which is the usual stimulus of the lungs. But the fact that Carbonic acid gas produces death much more suddenly than many other non-respirable gases, even when largely diluted by atmospheric air, seems to show that its absorption must con-

tribute to its suddenly fatal effects. These facts and considerations seem to show, that free Carbonic acid is not a constituent of blood.

§ 90. *Sudden death from air entering the jugular vein, explained.*

The Oxygen ignites the Hydrate of Carbon, and evolves Carbonic acid, which almost instantly reaches the pulmonic capillaries. This, as when entering from the pulmonic air vesicles, produces the like noxious influence, and accounts for sudden death.

§ 91. *Animal fat a reserve of fuel for calorification.*

Animal fat abounds in Carbon, and Liebig thinks it a reserve supply connected in some way with respiration and calorification ; although he has not explained how its Carbon is ignited. This is sufficiently shown by the previous explanation of the manner in which Carbon, derived from other sources, is employed in calorification. The large amount of fat which hibernating animals take into their retirement, supplies the necessary fuel for their long period of slumber.

§ 92. *Heat of fever.*

In fever, the source of Carbon, by way of food, is mainly cut off. Emaciation is rapid,

showing prompt absorption of the fat. There is a constant correspondence of activity in the three great functions of respiration, circulation and calorification.

The larger proportion of Carbon in animal fat than in ordinary food and the hurried respiration and calorification, constitute a combination of causes, which could not fail of producing a morbid degree of animal heat. As this store of Carbon becomes exhausted, the febrile heat necessarily moderates.

§ 93. *Fœtal physiology*, as usually taught, comes in direct conflict with the views of respiration and calorification which have been offered. It has been handed down from physiologist to physiologist, as a settled principle, that the placenta of the fœtus performs the usual office of the lungs in the adult; but, either this principle, or our whole theory of respiration and calorification, must be founded in error. The single circulation of the fœtus before birth, and the anatomical structure of the placenta, show no provision but for vegetable life; that is, to furnish and deposit, but not to carry off the refuse elements of the nutriment. There are no excretions,—no pulmonary or cutaneous vapors,—no Carbonic

acid discharged, nor is there any change of color in the foetal blood as it goes to, and returns from the placenta. There can, consequently, be no formation of Hydrate of Carbon, as in the adult, for calorification, no necessity for any pulmonary apparatus to decarbonize the blood. The elements of growth must, hence, be prepared by the maternal vessels and furnished through the medium of the placenta, in office analogous to the roots of vegetables ; while the heat is furnished from the mother or from some other exterior source, as in incubation. Until the lungs are set in play, the systemic capillaries cannot form, or send on for ignition to the pulmonary capillaries, the Hydrate of Carbon for calorification. The capillaries of the lungs in the foetus may, doubtless, as in the adult, perform the function of haematoisis, converting, by double decomposition, the free soda of the blood and perchloride of iron formed in the mother's stomach, into the hydrated peroxide of iron, that this may be in readiness for decarbonizing the vital fluids as soon as respiration commences.

§ 94. The sudden appearance of dots of red globules in the formation of new parts and vessels as these permeate the coagulable

lymph, admits a like explanation. The free soda and perchloride of iron being at the extremities of the previously colorless vessels brought together, there undergo a double decomposition, and thus complete the red globule.

§ 95. *The liver principally an organ of hæmatosis.*

Physiologists have expressed very different views of the function of the liver, many believing it principally an organ of excretion ; others that it is also an organ of hæmatosis. That soda is furnished by the gastric capillaries for the hepatic secretion, renders it probable that not only this important constituent of bile, but that various other materials are sent from the stomach and bowels to the liver for combination, during the process of chymification and chylification. Moreover, the diversity of elements constituting bile, the slow secretion thereof during the intervals of meals and its rapid secretion during digestion, appear to indicate that various alimentary substances may be absorbed for direct conveyance through the portal vein to the liver for new elaboration. That almost all the soluble parts of bile enter into the chylous fluids and are absorbed into the circulation, strengthens the belief that the prin-

cipal function of the liver is to combine in the globule of bile, the materials from the food to fit them for the subsequent formation of chylous fluids and blood.

§ 96. *An objection that Carbonic acid is evolved in the respiration of hydrogen and nitrogen, answered.*

An objection to this theory of respiration and calorification has been offered, at first view very formidable, viz : that of the evolution of Carbonic acid gas when nitrogen and hydrogen are respired. This fact seems to have confirmed Muller, Carpenter, and other distinguished physiologists, in the belief that Carbonic acid gas is an educt from the blood, instead of a chemical product of respiration. Muller expresses the belief that the experiments of Sir H. Davy and others upon warm blooded animals "are of no value," because they "can be kept in Hydrogen but a short time," and that their lungs "contain Carbonic acid at the commencement of the experiment." He thinks a long time necessary to such experiments, and cold blooded animals are accordingly made the subjects, because of their tenacity of life. But are experiments upon these more conclusive ? This class of animals evolve far less Carbonic

acid than warm blooded, and live far longer without the presence of Oxygen ; while in some, respiration appears mainly performed by the skin. The amphibia remain submerged for a considerable time, the whale about an hour, without a new supply of atmospheric air. It can hardly be doubted that frogs and all such animals, can carry in the air cells a sufficient supply of Oxygen to last them during their stay under water. Upon breathing hydrogen or nitrogen, it is fair to infer that respiration would alike go on for some time, before the supply of Oxygen would be exhausted, when the same effects would occur as in warm blooded animals. Until these occurred, the Oxygen would oxydize the Hydrate of Carbon and form Carbonic acid to be thrown off from the lungs. But Muller also states that "frogs fall into a state of asphyxia, when made to respire in hydrogen and nitrogen." Can it be reasonably doubted that the asphyxia occurs in both classes of animals from the like cause, the exhaustion of the air cells of Oxygen ? If not, oxydation of Hydrate of Carbon might obviously go on, till asphyxia suspended the respiratory movements in the cold bloded animals.

## CHAPTER XI.

## ANALOGIES AND DIFFERENCES BETWEEN ANIMAL AND VEGETABLE DIGESTION AND NUTRITION.

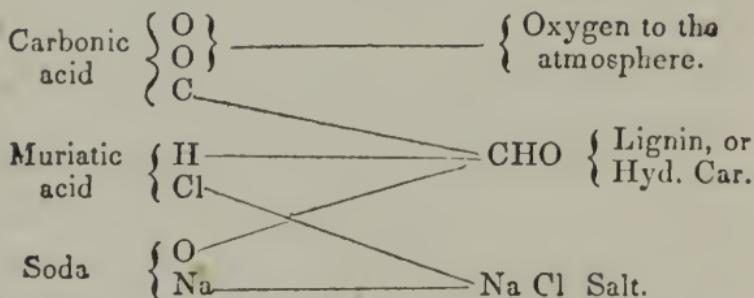
§ 97. We find in vegetable and animal fluids and solids the same compounds as the products of their vital movements, viz : albumen, fibrin, casein, and compounds of iron. As animals derive their food from vegetables, these compounds must be of *primary* vegetable origin. Organic compounds are all found in soils, especially in those rich in decaying animal and vegetable substances. In vegetables, as in animals, their elements must be rendered soluble in order to ascend in their capillaries ; whether or not vegetable digestion and nutrition consist wholly in an original elaboration of elements from inorganic nature. That some vegetables are essentially constituted from a primary elaboration of inorganic elements, is doubtless true ; but there can be little doubt that they also digest and deposit for nutrition, vegetable and animal compounds. In order to effect the necessary solution of the oxide of iron found in vegetables, some solvent like muriatic acid of the gastric juice of animals is indispensable. Common salt and water are

as necessary to vegetable as to animal life, and hence the wise Creator has provided that they shall always be in apposition in rain water, which contains common salt as a uniform constituent. The fact that fruit trees, which have been unproductive, will often yield abundantly by digging around them and depositing salt near their remote roots, is an evidence that salt is as necessary to vegetable as to animal digestion. Admit the truth of this deduction, and the explanation of the manner in which iron finds its way through the vegetable capillaries to form a constituent of their solid organism, becomes obvious. Double decomposition of salt and water by the radicals of the roots of vegetables, would, as in animals, furnish muriatic acid to dissolve the iron, converting it into the soluble perchloride, fitted for capillary ascent ; while soda would be simultaneously formed, ready to reconvert the chloride of iron into the *peroxide*, and also to re-form salt as soon as the iron reached the point of destination. The reason of salt being a uniform constituent of vegetables, must be obvious ; since when thus re-formed, there is no return circulation, as in animals, to carry it off as an excretion.

§ 98. *Formation of Hydrate of Carbon in vegetables.*

To form Hydrate of Carbon, according to all analogy, should require a like chemical action in vegetables and in animals. In animals we have shown (§ 82, *Diag. 9*) that each of three binary compounds yields an element by, what may be properly designated, *triple decomposition*, to form this compound for calorification. So in vegetables, carbonic acid (C), muriatic acid (H Cl) and soda (Na O) each yields an element to form Hydrate of Carbon ; thus,

DIAGRAM 14.



This is what may be called triple, or vital decomposition ; each of three binary inorganic compounds yielding an element to form the first and simplest triple compound of vital chemistry. We have shown by former facts that the very same carbonaceous combustible is

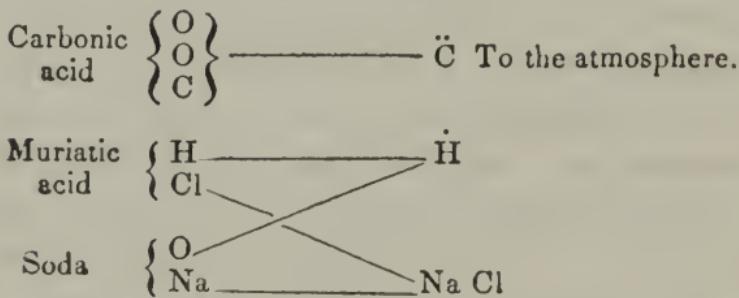
formed by diffusing carbonic acid in arterial blood, out of, as in the animal; and that this combustible Hydrate of Carbon must in both instances have been formed by the triple decomposition just stated.

Muriatic acid and soda formed by the radicles of vegetables, carry up in solution the elements of vegetable growth, and evolve them where their double decomposition furnishes the elements of water to form the Hydrate of Carbon, as in animal *nutrition* (*Diag. 9, § 82*). Here also, there being no return circulation (as in animals) the Hydrate of Carbon is deposited as the essential, solid structure of plants (analogous to the bones of animals,) while in animals, the Hydrate of Carbon is used in their functions of calorification and respiration. These functions in animals, as compared with vegetables, seem to be superadded and intermediate between those of digestion and nutrition.

§ 99. Another difference of animal and vegetable physiology has already been noticed, that of the Oxygen of the Carbonic acid being thrown to the atmosphere in vegetables, but not in animals. This triple decomposition of Soda, Muriatic and Carbonic acids does not occur except when the vegetable is subjected

to the influence of the sun's rays, while Carbonic acid, undecomposed, passes at other times from the leaves. This is beautifully illustrated in the growth of water plants under ice, as before noticed (§75). Vegetable growth takes place even where the sun's rays are not admitted as in mines; and it is doubtless true that it continues during the night, although the Carbonic acid is not then decomposed to form Hydrate of Carbon. This growth of vegetables in the absence of light, may be illustrated thus :

DIAGRAM 15.



The Carbonic acid (C) instead of yielding Carbon to form Hydrate of Carbon at the leaves, as when the sun shines (Diag. § 95), is given off unchanged to the atmosphere, while the water (H) and salt (NaCl) recomposed, remain as constituents of the plant. Any organic elements, such as fibrin, albumen,

or casein found in soils, or the inorganic earthy elements, such as iron, lime, &c., are rendered soluble by the muriatic acid and soda at the roots (§ 83 *Diag.* 10). After ascending in the sap they would be deposited for the *nutrition* of the vegetable after the recombination of salt and water, as in the nutrition of animals (*Diag.* 12, § 85). The water thus re-formed, remaining *fluid*, instead of helping, as when the sun shines, to compose *solid* Hydrate of Carbon, accounts for such vegetables as grow in the dark being more succulent and less solid, than others.

§ 100. These analogies of animal and vegetable digestion and nutrition, show why vegetables contain the alkalies or chlorides, as constituents of their solid organism, while animals do not ; these throwing them off as *excretions*, after the soda and muriatic acid have served their office of carriers.



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**E R R A T A.**

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Page 9, line 6, for § 11 read § 10.

Page 38, line 15, for § 31 read § 30.

Page 103, line 15, for radicals read radicles.



Spencer, Thomas, *Lectures on animal heat*

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